VOLUME XLIII NUMBER 6

BOTANICAL GAZETTE

JUNE 1907

THE INFLUENCE OF TENSION ON THE FORMATION OF MECHANICAL TISSUE IN PLANTS[1]

RUFUS PERCIVAL HIBBARD

The radical change from a theory of self-regulatory development of mechanical tissue in plants subjected to tension by pull, to one implying no reaction whatever, necessitates detailed evidence before the latter can be accepted. The following investigation was directed to a more complete knowledge of the reactions of a plant to tension, to determine if possible what influence this exerts on the formation of mechanical tissue. Heretofore the root system has been entirely ignored, but this together with the stem has been included in the work here recorded.

I. Historical

For some time previous to 1891, physiologists had generally assumed that a plant reacted to a gradually increasing strain by a development of its mechanical tissue. HEGLER (PFEFFER '91) in this year subjected several stems and leaves to a longitudinal pull. In response to this method of experimentation, the plant, according to HEGLER, withstood greater strain than one grown under normal conditions. For example, a seedling of *Helianthus annuus* whose original breaking strength was 160^{gm} had a breaking strength of 250^{gm} after two days under the influence of a pull of 150^{gm}. The petioles of *Helleborus niger*, which at first could withstand a weight of only 400^{gm}, after five days, during which the weights had been gradually increased, held without breaking 3.5^{kg}, while those under normal conditions gained but little strength in the same time. Marked differences were

[1] Contribution 92 from the Botanical Laboratory of the University of Michigan.

apparent, not only in the tensile strength, but also in anatomical structure. On examination of various sections, HEGLER noticed (1) a numerical increase in the cells of the collenchyma; (2) an increased thickness of the walls of the collenchyma, sclerenchyma, and bast; and (3) the production of entirely new tissues. These observations led him to the conclusion that a plant responds to a gradually increasing strain by a development of mechanical tissue. It is indeed unfortunate that only a preliminary report of HEGLER'S work can be had. The influence that his conclusions exerted has been widely felt, and the principles laid down were widely accepted.

RICHTER ('94) concluded that when the stems of Chara were pulled longitudinally, there was an increase of strength. Thus, in his opinion, he confirmed the observations and results of HEGLER. But we may dispose of this interpretation in the words of BALL (:04), who says: "Die Resultate RICHTERS sind etwas zweifelhaft, da er keinen Vergleich zwischen belasteten Chara-Pflanzen und unbelasteten von demselben Alter und derselber Grösse gegeben hat."

VON DERSCHAU ('94) came to the conclusion that a gradually increasing pull without contact on certain twining petioles raises the breaking strength, increases the development of mechanical tissue, and calls forth the development of new tissue. His first statement is borne out by experiments which show that even after twenty-four hours the plant part under strain could withstand a weight which at first would have broken it. From a study of sections of the various petioles, he found that marked anatomical differences occurred. There was a numerical increase in almost all kinds of cells. The bast thickened in all the petioles examined except those of *Solanum jasminoides*, and the ring of vascular bundles was made complete in all but Solanum, where it was half-moon shape, as in the normal petioles.

Concerning tendrils no experiments have been recorded to determine the effect of pull alone on the free basal portion. PENHALLOW ('86, p. 49) noted that tendrils that had secured attachment were larger, stronger, and more rigid, from which it would appear probable that contact produces a more or less marked effect in accelerating or at least in increasing the strength of parts. This view gains strong confirmation from similar conditions in Ampelopsis.

WORGITZKY ('87), in his "Vergleichende Anatomie der Ranken," gives the results of weighting experiments, and comes to the same conclusions as VON DERSCHAU. He found, by comparing weighted tendrils of *Passiflora quadrangularis* which had secured attachment with weighted tendrils which had not, that the tensile strength of the former had increased about twice as much. With tendrils of *Curcurbita Pepo* the resistance to strain was increased thirteen fold. This he believed was not the result of pull alone, but one of pull and contact combined.

NEWCOMBE ('95, p. 446), speaking of the reaction of tendrils to contact, states "that the first strengthening tissue is here laid down as a response to contact; its increase is the regulatory response of the plant to the strain that it feels."

MACDOUGAL ('96, pp. 377, 378) believes that contact stimuli are not transmitted beyond 2 or 3^{mm} and, as the thickening of the tendril always takes place after contact, we are left to conclude that it is due to the pull or traction exerted by the weight of the stem supported by the tendril.

PEIRCE (:04, p. 241) believes also that the strengthening of the free basal portion is not due to contact, but to the pull exerted in bringing the stem nearer the support.

FITTING (:03, p. 476) has lately shown that contact stimuli are transmitted for some distance, and for that and other reasons their effect on the basal portion of the tendrils cannot be excluded. It thus becomes a question how much of the increase of strength is due to pull and how much to contact.

VÖCHTING (:02) investigated the influence of pull on sunflowers and cabbages that had been prevented from flowering by means of decapitation, and found that no new tissue had been formed and that no increase of mechanical tissue had occurred as a result of the pull.

WIEDERSHEIM (:03) finds that the expected development of new tissue and the thickening of the wood and bast fibers in weighted pendent branches of Fraxinus, Fagus, Sorbus, and Ulmus does not occur. On the other hand, in Corylus he observed an increase in the number of bast fibers. This he attributes to a self-regulatory development.

BALL (:04) repeated the work of HEGLER. As a result of numerous

experiments to determine exact conditions, he has been able to show that in general the breaking strength of a plant stem does not increase in response to a gradually increasing pull, and that no increase of breaking strength follows as a result of pull on a stem growing in a horizontal plane. Detailed examinations of microtomic and free-hand sections, stained and unstained, show that there is, as a result of pull, no increase in the thickness of the walls, nor a numerical increase in the cells of the various tissues. No new tissues are produced as a result of the strain. A number of other authors, KÜSTER (p. 173), PFEFFER (**:01,** p. 148), and VÖCHTING (p. 282), have also failed to detect or observe any production of new tissues.

The factor of correlation has yet to be briefly mentioned. It is generally admitted by writers who have investigated the subject that a very high degree of correlation is manifest between the various organs of the plant. GOEBEL writes in his *Organography of Plants* (p. 206) "that careful research demonstrates the existence of reciprocity between parts of the plant body. . . . . The size and construction of one organ are frequently determined by those of another."

KLEIN (**'86**) showed that the bundles were more centrally located in the fruit stalk than in the petiole, and attributed this arrangement to the necessity for a greater mechanical strength, as well as for a more abundant supply of building material.

DENNERT (**'87**) on comparing the anatomical structure of the fruit stalk, before and after ripening of the fruit, found an increase in the development of mechanical tissue. This was apparent in the greater increase in the xylem and in the thickness of walls of the wood fibers.

REICHE (**'87**) corroborates the work of the earlier investigators and shows in many additional plants that changes in the flower stalk during its transformation to a fruit stalk go hand in hand with the development of the fruit.

PIETERS (**'96**) showed that although one-year-old fruit-bearing shoots of the apple and the pear had a smaller xylem cylinder in proportion to their diameters than the vegetative shoots of the same age, they were well supplied with supplementary mechanical tissues which was distributed at those points where it was most needed. In the case of the peach and the plum, the woody cylinder was larger in the fruit-bearing shoot than in the vegetative shoot. Fruit-bearing also

exerted an influence on the lignification of the cell walls of many of the tissues in the stalk. In the apple and the pear there was an abundance of well-lignified sclerenchyma and hard bast, which occurred in the vegetative shoot only sparingly, if at all.

BOODLE (:02) states that the walls of the sieve tubes and companion cells in *Helianthus annuus* become lignified as a result of strain. We also read "that the slight lignification of the parenchymatous parts of the pericycle and medullary rays unites the primary sclerenchyma strands into a more definite mechanical system attached to the strong xylem by the medullary rays." Finally, he says, "this must give greater rigidity, which no doubt is required by the heavy fruiting capitula borne by the plant."

On the other hand, in opposition to this theory, KELLER (:04) finds that pull as such does not call forth a regulatory strengthening of mechanical tissue in fruit stalks. Fruit-bearing in itself does not cause a thickening of parts nor exert an influence on the lignification of the cell walls. Upon orthotropic flower stalks, a strong or light pull in the direction of the long axis exerts no influence on the development of mechanical tissue. Displaced stalks under tension show no self-regulatory thickening, but certain anatomical changes do take place. These changes are not due to tension, but simply to the alteration in the position from orthotropic to plagiotropic, and in turn are directly referred to differences in the degree of strain between the upper and lower sides. These conclusions do not fall in line with the view that has held ground for some time, namely, that the mechanical development of the stalk goes hand in hand with the development of the fruit. Correlative growth, it is said, is no explanation for this phenomenon. This interpretation is yet to be justified. If this be true, our previous ideas must undergo transformation.

As a conclusion of the historical part of this paper I might summarize these views: Tension has no influence on the increase of mechanical tissue in any stems examined, in any petioles, nor in branches, except in *Corylus avellana*. It has some effect on twining petioles in that there occurs a thickening and lignification of certain tissues. The effect on tendrils has not yet been accurately determined. Until further data are gathered to show the contrary,

compensatory regulation or correlative growth cannot be considered as an unimportant factor.

II. Methods

The seedlings and plants examined in my work were *Helianthus annuus*, *Phaseolus multiflorus*, *Ricinus communis*, *Brassica oleracea*, *Coleus tricolor*, *Fuchsia speciosa*, and *Vinca major*. The stems compared were selected with reference to similarity in size and vigor. All tension and normal plants were grown under similar conditions.

When collected, the stems were numbered, cut into suitable lengths, and put into 50 per cent. alcohol for further examination. To study the stems, freehand cross-sections were made and the tissues measured by several methods. Further description of the different methods will be given under the proper headings.

III. Results of experimentation

A. INFLUENCE OF TENSION ON STEMS

A number of seedlings were subjected to tension in the following manner: Strong, light twine was fastened about the stem, which had previously been wound with cotton flannel to eliminate any injury due to the cord. The twine was then run over a lightly rolling pulley, hanging from a support directly above, and the weights attached to the free end of the cord. The twine was so fastened that very little injury, if any, was caused. Two loops were made from short pieces of twine, each about 30^{cm} in length. These were noosed about the stem, from opposite sides one within the other, so that four circles of twine surrounded the stem over the cloth. The ends of the loops were then connected by a short piece of twine. To this was fastened, in an adjustable manner, the cord running over the pulley. In this way, if one loop should happen to be longer than the other, an adjustment took place, so that the strain on each loop was the same, in consequence of which the stem felt the pull in the direction of its longitudinal axis.

When the seedlings were young, the unfolding leaves and growing tips might be somewhat hindered in their growth by the interference of the loops of twine. To prevent this, a strip of light whitewood, about 10^{cm} long, 3^{mm} wide, and not more than 1.5^{mm} thick, was so placed between the loops as to form a diamond-shaped figure, such as

has been described by BALL (p. 309). When the plants had reached a more advanced stage of development, this device was unnecessary, and was therefore discarded. To guard further against any possible injury that the cord might produce in the stem when heavy weights were used, the cord was frequently changed to a place above or below the original attachment.

The seeds were germinated in 20^{cm} pots containing garden loam and clay. The loam and clay were thoroughly mixed in the proportion of one of garden loam to three of clay. This gave the earth a firm cohesion, and for this reason few seedlings were uprooted. When necessary, a plaster of Paris cap was cast over the earth to the edge of the pot and securely fastened with cord. The plaster was kept from the stems by means of surrounding paper cylinders. When the seedlings had reached a height of 8 to 10^{cm}, the experiments were usually begun, although in some cases they were allowed to grow stronger and taller before being subjected to tension.

There are two ways to determine whether or not tension has increased mechanical tissue. First, by a measurement of the breaking strength, and second, by the observation of the size of the various tissues and the thickness of the cell walls. The first method has been followed admirably on various stems by BALL. Beyond a few experiments performed by the writer, the need of further observations by this method seems quite unnecessary.

To determine by microscopic means the differences between tension and normal plants in the mechanical tissues, several methods were used. One method was to determine the thickness of tissues and walls by an ocular micrometer. The areas of the woody cylinders were computed by making camera-lucida drawings of the xylem, and the areas of these irregular drawings were determined by means of a polar planimeter. A third method was devised of making camera drawings of the woody cylinder on Bristol board, which were then carefully cut out and weighed on a chemical balance. A fourth method consisted in comparing the phloem bundles of the tension and normal plants. The number of bast fibers in cross-section of a tension plant was compared with that in the bundles of the normal plant. The number of bundles in one was directly compared with the number in the other. A fifth method consisted in comparing

sections of the tension-plant stem above and below the place of attachment of the cord, to note any differences in anatomical structure in the two regions.

Helianthus annuus (greenhouse cultures)

Ten plants of *Helianthus annuus* that had grown in the greenhouse for a month were weighted on November 4 with 50^{gm}. On the third day following, the weight was increased to 100^{gm}, and on the tenth to 200^{gm}. At this time the attachments were changed to a place above the original one. This, as has been mentioned above, was for the purpose of guarding against injury due to the cord. Additional weights were added at various times, until in this set of experiments the final amount reached 600^{gm} on November 23.

At this time the weights were removed from five plants and the stems placed in 50 per cent. alcohol. Five plants that had grown under similar conditions, except that they had not been subjected to tension, were also gathered to serve as controls. These controls had been chosen at the beginning of the experiment and were closely watched throughout the time of experimentation in order that all conditions other than tension should be the same.

Cross-sections of the normal stem of *Helianthus annuus* of this age, at a height of 7^{cm} from the ground, do not show a completely closed xylem ring. The bundles are separate and are of various sizes. The secondary xylem is beginning to form.

Sections for microscopical study were made at a place 7^{cm} above the first lateral root in both tension and normal plants. The place of attachment of the cord on the tension plant was some distance above this, so the sections were within the region of tension. Careful observations by two persons, working independently, did not disclose any appreciable difference between tension and normal plants.

Other sections were then made in the tension stem above and below the attachment. No appreciable differences are detected when sections in the tension region are compared with sections on the same plant out of the region of tension.

As a general result of observations of the first five plants, we may say that tension exerted upon the stem along its longitudinal axis did not call forth a self-regulatory development of mechanical tissue.

The remaining five plants of the ten used in the above experiment were allowed to grow with the constant pull of weights until they had produced flowers. The purpose of this experiment was to note the influence of tension continued for a long period. These plants because of the winter season were rather weak. Cross-sections of these stems at 7^{cm} above the ground show a closed xylem ring. The area and weight methods as described above were employed for detecting differences. Even in these examples we find no self-regulatory development of mechanical tissue in response to tension, nor are the results on old stems any different from those on young ones. The final weight carried by each plant was 2300^{gm}.

The above experiments on *Helianthus annuus* were repeated with twenty-five other individuals and the same methods for detecting differences were used. Only a few of these plants were allowed to mature, as young plants give just as reliable results and are much more easily handled. The duration of the experiments varied from two to four weeks. The final weights varied from 600^{gm} to 2860^{m}. The general result was that tension, gradually increased and in the direction of the longitudinal axis, did not induce a self-regulatory development of mechanical tissue in the sunflower stem. In this we agree fully with the results of BALL.

Helianthus annuus (field cultures)

Seventeen sunflower plants were subjected to the same condition of strain, but to other external conditions which were not so uniform as those in the greenhouse. These experiments were conducted in the open field during the months of July and August 1905.

An examination of the cross-sections of these stems, taken at 1^{cm} above the first lateral root, gives the general result that was found to be true in the case of the plants grown in the greenhouse, namely, that an increasing tension along the longitudinal axis does not call forth a self-regulatory development of mechanical tissue in the sunflower stem. By the area method only three tension plants show an increase of mechanical tissue over that of the controls. Two control plants show an increase in mechanical tissue over that of the tension. The others show slight differences that fall within the limit of error. Ten examples from the seventeen are given in Table I.

TABLE I

Plant	Tension	Normal	Percentages (Normal = 100)
No. 1 A.	29.87 sq. cm.	31.16 sq. cm.	− 4
No. 2 B.	42.45	42.71	− 6
No. 3 B.	17.42	17.29	8
No. 4 B.	23.74	23.23	2
No. 5 B.	35.62	54.52	−53
No. 10 B.	33.68	51.81	−54
No. 9 A.	53.16	31.81	67
No. 5 A.	56.13	36.45	54
No. 8 A.	55.04	49.42	11
No. 1 B.	34.65	32.65	6

In the above table the second column contains the measurements of the relative area of xylem in the tension plant in section; the third column contains similar measurements in the control plants in section; and the fourth column contains percentage differences when the normal is taken as 100.

Ricinus communis (field cultures)

The same experiments were made upon Ricinus stems, which were also cultivated in the open field during the summer months. Seventeen, chosen at random, from the large number that were put under tension, showed after close observations the same general results as previously indicated for Helianthus. There is no constant increase in mechanical tissues as a result of a gradually increasing pull. The following table shows results of observations on ten plants.

TABLE II

Plant	Tension	Normal	Percentages (Normal = 1)
No. 1 A.	24.20 sq. cm.	17.10 sq. cm.	42
No. 2 A.	59.615	39.87	50
No. 3 A.	26.45	23.915	11
No. 5 A.	52.50	59.9	−14
No. 9 A.	52.39	56.555	− 8
No. 10 A.	45.00	55.7	−24
No. 3 B.	30.10	24.6	23
No. 4 B.	35.30	33.9	4
No. 5 B.	15.80	15.40	3
No. 7 B.	50.30	48.70	3

Nos. 1A, 2A, 3A, and 3B show results in favor of tension plants; nos. 5A and 10A show results in favor of normal plants; nos. 9A,

4B, 5B, and 7B are within the limit of error. The remaining seven of the original seventeen were estimated with the aid of the microscope. These in nowise alter the general conclusion.

Vinca major (greenhouse cultures)

Twenty-three thrifty young stems of *Vinca major*, some of which were still growing upright, and others that had already bent over and were growing in the usual drooping way, were subjected to tension by means of weights. The young upright stems were placed under tension in the same manner as explained above for *Helianthus annuus*. The pendent stems were placed under tension by hanging the weights upon them without the use of the pulley. Cotton flannel was wound around the stem just above a node. Two loops of twine were then noosed around the stem over the cloth, and drawn tight. From the end of each noose hung equal weights, and thus the stem received the strain along its longitudinal axis.

The duration of the experiments on the upright stems varied from two to four weeks, and the final weights varied from 1250 to 1500^{gm}. The duration of the experiments on the pendent stems varied from eleven to twenty-eight days, and the final weights varied from 1000 to 1500^{gm}. Normally growing stems for comparison with tension stems were selected with regard to similarity in diameter, length, manner of growth, and vigor. In most cases sections were taken in normal and experimental plants at equal distances from the stem apex.

Observations with a magnification of 100 diameters show that in the majority of plants the whole xylem ring is thicker and composed of thicker-walled cells in the tension plant. The bast is more abundant in the tension plant. Under a higher magnification of 150 diameters, it is noticed that the walls of the bast fibers are thicker in the tension plant.

In all of the twenty-three plant stems under tension, five only do not show an increase in the absolute size of the xylem or in the thickness of the cell walls of bast or xylem. The following tables give the results obtained for a few of the representative plants and their controls. The preponderance of evidence, judging from the number of plants experimented on, shows that an increase in the quantity of xylem amounts to at least 50 per cent. In the table, T indicates

tension plant, and N the control. The areas given are those measured on the drawings.

TABLE III (AREA METHOD)

Plant	Area of whole section	Area of xylem and pith	Area of xylem	Percentages
No. 2A. T.	97.75 sq. cm.	35.62 sq. cm.	15.29 sq. cm.	53
No. 2A. N.	97.62	34.32	10.00	
No. 3 T.	153.49	60.64	20.13	82
No. 3 N.	154.20	61.62	11.03	
No. 2B. T.	129.49	53.75	14.65	− 3
No. 2B. N.	125.10	50.13	15.03	

The last plant (no. 2B. T) is one of three mentioned above. This shows a slight difference in favor of the normal and by so much weakens the general conclusion.

The first four plants of the preceding table were used to test the differences by the weighting method. The two methods show results which are very close, only varying by 2 per cent. to 4 per cent.

TABLE IV (WEIGHT METHOD)

Plant	Weight of drawing of cross-section	Weight of xylem	Percentages Difference
No. 2 T.	1.87 gm	0.28 gm	49
No. 2 N.	1.89	0.19	
No. 3 T.	2.8641	0.382	78
No. 3 N.	2.9301	0.215	

Brassica oleracea (greenhouse cultures)

Five plants of *Brassica oleracea* were put under tension in a similar way as explained for *Helianthus annuus*. The seeds were planted in 20 cm pots and placed in the greenhouse. In a little more than a month these had grown sufficiently for experimentation, being about 7 cm tall. The original weight for each plant was 50 gm; this was gradually increased until the final weight reached 1000 gm. The duration of the experiment was two weeks.

Sections were made freehand at places 5 cm and 1 cm above the ground in both control and tension plants. An examination of the various anatomical structures failed to show any constant differences between the control and experimental plants. The xylem ring in the

tension plant when compared with the xylem ring in the control plant showed no appreciable difference. The phloem in each had developed to the same degree. Under high power the walls of the cells in the tension plant were seen to be no thicker than the walls of the corresponding cells of the normal plant.

A further study, such as has been made with other stems by determining differences with the aid of area or weight methods, seemed unnecessary. It must be concluded then, as a result of experiments on five plants of *Brassica oleracea*, that tension does not call forth a self-regulatory development of mechanical tissue.

Phaseolus multiflorus (greenhouse cultures)

Four plants of *Phaseolus multiflorus* were subjected to tension for two weeks. These plants were cultivated in the greenhouse and when a few centimeters high were put under a strain in the same manner as explained for Helianthus. Small weights were first attached, and to these were added others until the final weight amounted to 1750^{gm}. Freehand sections were made at heights on the stem 5^{cm} above the ground. Sections at corresponding places in the control plants were chosen for comparison. Control plants, as in all experiments, were selected with reference to similarity in growth, size, and vigor.

In cross-section the stem of Phaseolus shows a very well-differentiated xylem ring, and it is very easy to note differences if they occur, when tension and control plants are compared. In the four plants under experimentation, a careful inspection with the microscope failed to show any appreciable differences in the size of the xylem ring, bundles of phloem, or thickness of walls. For this reason it seemed unnecessary to proceed with the various methods as used in previous experiments. My conclusion, therefore, with reference to the influence of tension on the stem of *Phaseolus multiflorus* can be nothing else than that tension does not induce a self-regulatory development of mechanical tissue.

Conclusion

From the above seven experiments we conclude that tension has no influence in the formation of tissue in stems of *Helianthus annuus*, *Ricinus communis*, *Brassica oleracea*, and *Phaseolus multiflorus*, but that in Vinca it seems to call forth a regulatory development of sup-

porting tissues. This shows itself in an increase in the amount of xylem and in the thickness of the cell walls of the same.

B. INFLUENCE OF COMPRESSION ON STEMS

In my experiments I made use of the following plants and seedlings, which were cultivated in the greenhouse: *Helianthus annuus*, *Vinca major*, *Fuchsia speciosa*, and *Coleus tricolor*. The controls were raised in the same place, and received the same care and attention as the plants under experimentation.

A number of the above-named plants and seedlings, young and old, were subjected to compression by various means. The most common means was that of fastening the weights directly upon the stem. Around the stem, some distance above the ground, usually not more than 15^{cm}, a strip of cotton flannel was wound. Over this and around the stem from opposite sides were noosed two loops in the manner already described in the tension experiments on Helianthus, Vinca, etc. Equal weights were attached to each loop, so that the strain was uniform on the opposite sides of the stem. To insure the stem from bending under the weight, bamboo stakes were driven into the ground close to the plant and then fastened to it in two places, one above and one below the place from which the weight hung, but so fastened as not to free the plant from the compression of the weights.

In other cases the compression was narrowly localized. This regional compression was brought about in the following manner: Weights were hung from the sides of the stem as has already been explained. Below the attachment of these weights, some 10^{cm} distant, a strong cord was fastened about the stem in the manner as described for the tension experiments. This cord was run over a pulley fixed to a support directly above, and to the distal end of the cord were fastened weights equal to those hanging on the plant. By this method, a weight above pressing down and another below pulling up, there was a compressed region; while the upper and lower parts of the stem were free from compression.

Variation in the method of hanging the weights on the plants was employed, but these details are of minor importance, and will not be given here.

Helianthus annuus

Twenty-six sunflowers were subjected to compression by the different methods explained above, the method depending upon the size and age of the plant used. Seedlings were cultivated in 20^{cm} pots in the greenhouse. The duration of the experiments varied from two to five weeks. The weights varied from 400 to 2100^{gm}. As a general result of this experiment one may say that a compression strain will call forth slightly increased mechanical development in a majority of the plants used. This expresses itself in a slightly greater thickness of cell wall and xylem cylinder. The phloem bundles are also slightly larger.

Fuchsia speciosa

Five small Fuchsia stems were subjected to a compression strain of 185^{gm}. No bending was present to modify the anatomical structures. Sections were taken from the stems within the region of compression at distances from the ground varying from 5 to 8.5^{cm}. Sections of the normal stems taken at corresponding places were selected for comparison. With the aid of an eye-piece micrometer, measurements of the xylem cylinders were made in two directions at right angles to each other. The average of these two measurements was taken as the average width of the xylem ring. Data so obtained indicated a greater thickness of xylem in the tension plant than in the control, but the increased mechanical development was not strong.

Vinca major

Eight young upright Vinca stems were subjected to compression by hanging the weights upon them. To prevent bending, the plants were tied to a support in the usual way, the final weight carried by each plant being 200^{gm}. The period of experimentation extended from March 10 to March 25. Control plants were selected with reference to the same age, growth, and vigor. Sections taken in the region of stress were compared with sections taken at corresponding places in normal plants.

Observations under the microscope indicated, in a majority of the plants experimented upon, that a compression strain causes slightly increased development of mechanical tissue.

Coleus tricolor

Four young and thrifty Coleus plants were put under compression in a similar manner as explained for Fuchsia. After a period of twelve days under a compression strain of 225^{gm}, they were gathered and together with their controls were placed in 50 per cent. alcohol for examination later.

Observations under a magnification of 150 diameters revealed no evidence of any differences between control and tension plants. We are hardly justified, then, in concluding that in these Coleus plants compression exerts any influence toward a development of mechanical tissue. For reasons that are apparent, the absolute amounts of xylem in both normal and tension plants were not determined by either the area or weight methods. The conclusion drawn was the result of detailed observations under the microscope by two persons working independently.

Conclusion

The foregoing experiments were performed to determine the influence of longitudinal compression upon the formation of mechanical tissue in the stems of *Helianthus annuus*, Vinca, Fuchsia, and Coleus. The results indicate that the stems of all the above-named plants except Coleus reacted to a compression strain by a self-regulatory development of mechanical tissue, yet the evidence cannot be called conclusive.

C. INFLUENCE OF TENSION ON THE ROOT SYSTEM

A number of papers on the influence of pull, or tension, on stems, petioles, and other aerial organs have been published, but nothing as yet has reached print concerning the influence of this treatment on the root system. It is the purpose of this section of the paper to give the results of experiments along this line, and to show that in the root system we have an organ that reacts to tension by a self-regulatory development of mechanical tissue.

Tension on the root system was applied by means of a pull upon the stem, brought about in the usual way by weights, when the seedlings had grown to a height of about 15^{cm} and the first pair of leaves had fully developed.

The seeds for any one series of experiments on *Helianthus annuus*

were chosen from the same head. No further selection was made. The Ricinus seeds were all taken from one variety. All the seedlings used for these experiments, except where otherwise indicated, were cultivated in an open field during the summer of 1905. The ground was carefully prepared with a mixture of clay, swamp muck, and manure. This was thoroughly spaded, and afforded a rich, firm soil, from which the seedlings were not easily uprooted when under tension.

Two series of experiments were run through, one in the earlier and the other in the later part of the summer. The duration of the experiments was generally two weeks, after which time the plants were dug up, together with their controls, and their root systems carefully washed and placed in 50 per cent. alcohol. The root systems of control and tension plants were first compared with reference to their external form and size and later with reference to their internal structures. The control plants were chosen from the same locality in which the plants under experimentation were grown and were selected with reference to similarity in size and vigor.

I. EXTERNAL ROOT FORM

To determine the influence of tension on the root system, a careful and close comparison was made between the control and tension plants. Special attention was given to observations upon the main and secondary roots. At times it was noticed that the lateral roots attained a greater development on account of the small or aborted growth of the main root. On the other hand, the main root would sometimes reach quite an enormous growth, in consequence of which the lateral roots would not attain the usual size. This great growth of the main root occurred far less frequently than that of the lateral roots. Thus what may be called a compensatory regulation holds true with reference to these two orders of roots. This compensatory regulation, then, must not be confused with the evident strengthening and increased development of roots due to tension. In our comparisons of the normal and tension plants this fact had always to be kept in mind.

The number, average length, and generally vigorous condition of the roots and rootlets were determined. It was found that in general the main root of the tension plant was straighter, tapered more

gradually, and attained greater length; the lateral roots were generally more numerous, larger in cross-section, straighter, and longer. The greatest growth of lateral roots was always found at the crown of the main root near the surface of the ground.

Helianthus annuus

To show the differences in root form between the normal and tension plants, two series of experiments were made on *Helianthus annuus*. The results of both were in general the same. All plants compared were of the same size and were grown in the open field under similar conditions. The first series was under experiment from July 8 to July 21, the second from September 21 to October 10. The final weights to which the plants were subjected varied from 750 to 1000^{gm}.

The following are observations obtained from a comparison of the root systems of two seedlings of the same relative size and vigor. These were representative seedlings and the results obtained were characteristic of the entire set of thirty-four plants: The main root of the tension plant was straight for a distance of 6^{cm}, that of the control plant undulate throughout its whole course. The main roots had the same diameter at the upper ends. At 5^{cm} below the first lateral root, the diameter of the tension plant was 3^{mm}; while that of the normal plant was 2^{mm}. The normal plant had a cluster of 10 lateral roots at the upper end with a diameter of 1^{mm} or more; while the tension plant had at its upper end a cluster of 13 lateral roots with a diameter of 1^{mm} or more. All these were longer, much more branched, and in general appearance stronger than the lateral roots in the normal plant.

Here the differences between normal and tension plants were very marked, and it will be noticed later that marked differences appear as a result of microscopic observations.

Ricinus communis

The same general differences in external root form are noticeable in *Ricinus communis*. With this, as with the sunflower, two series of experiments were run through. The first was under experimentation from July 5 to July 21, and the second from September 26 to

August 11. The final weights held by the plants under tension varied from 1800 to 2000^{gm}.

The results of a comparison of two plants of *Ricinus communis*, selected with reference to similarity in all respects except in the matter of tension, are added below. The results here obtained are in general the same in the other sixty-seven plants used in the experiment.

The main root of the tension plant was straight throughout its whole course, that of the control undulate. The main roots had the same diameter at the upper ends. At 5^{mm} below the first lateral root the diameter of the tension plant was 4^{mm}, while that of the control was 3^{mm}. The control plant had a cluster of 18 lateral roots at the upper end with a diameter of 1^{mm} or *less;* while the tension plant had at its upper end a cluster of 23 lateral roots with a diameter of 1^{mm} or *more*. The lateral roots in the tension plant were much longer than those of the control plant. The root system of the tension plant was noticeably stronger in general appearance.

The results of these experiments on seedlings of *Ricinus communis* show how different the root systems of the plants under tension are from those growing under normal conditions. In every respect the differences are quite marked. Similar experiments conducted in the greenhouse with both Helianthus and Ricinus plants show like results.

From the above data one may conclude that tension causes a thickening and strengthening of the roots of *Helianthus annuus* and *Ricinus communis* grown in the open or in the greenhouse.

2. INTERNAL ROOT STRUCTURE

For a study of the internal root structure, freehand sections of the main and lateral roots were made. Sections of the main root were generally taken in two places, one near the top and the other some distance below. Sections of the lateral roots were made 1 to 2^{mm} from their insertion on the main root. The lateral roots to be sectioned were taken from the upper cluster of rootlets or from a position on the main root not lower than 1^{cm} from the first large lateral root. More than one lateral root on each plant was sectioned so as to obtain average results. The strongest and the average rootlets were always selected for comparison. No rootlet was chosen

unless it looked healthy, reached a fair length, and had a number of branches. Often the largest lateral root of the normal plant was not so large as the largest in the tension plant. This was sometimes taken as evidence of greater growth due to tension, but the results were not based on this fact alone. From the tension plant was selected a rootlet which was as large and vigorous as the largest rootlet in the normal plant. A comparison could then be made and the results, whatever they were, could be accepted without further allowance or additional estimation.

Helianthus annuus

Sections were taken of the main root at various points below the first lateral root. These were compared with sections taken at corresponding places in the control plant. The diameters of the sections of the normal root averaged 1^{mm} greater, and for this reason a better mechanical growth would be expected in the control. As the result of careful observations the xylem was found to be greater in amount and the cells were thicker-walled in the tension plant than in the normal. In cases where the diameter of the sections of the normal and tension roots were the same, the tension root always showed the greater amount of xylem and thicker-walled cells.

From a comparison of the rootlets at the crown of the main roots of the tension plants with those from the corresponding place in the control plants, it was seen that the former had a larger size, and microscopical study emphasized this fact and showed that the xylem cylinder was larger and the walls of the cells thicker in the tension plants. Rootlets of average size taken from tension plants were compared with others of the same size, vigor, and growth taken from the normal plants. The comparison showed that the tension plants had a larger amount of xylem and cells with thicker walls.

To recapitulate, we may say that, out of five Helianthus plants under tension, the main roots of all show a better development of mechanical tissue than the main roots of five control plants of similar development. With reference to the lateral roots, the majority in the experimental plants showed a better mechanical development than similar rootlets in the control plants.

Ricinus communis

It may be said by way of summary that twenty-five out of the thirty-four Ricinus plants under tension in this series show a greater development of mechanical tissue in both the main and lateral roots than in the control plants. Sections of the primary roots show considerable differences, while the secondary roots show some but not so great differences in favor of the tension plants.

Helianthus annuus

The plants for comparison were chosen from the series of experiments in the open field during the latter part of the summer. The evidence obtained from observations upon the main roots of twelve seedlings of *Helianthus annuus* shows that nine reacted to tension by an increased development of mechanical tissue, while all the lateral roots examined showed a greater development of mechanical tissue in the tension plants.

IV. Summary

In the foregoing work, of the five stems tested for the increase of mechanical tissue under the influence of longitudinal pull, only that of Vinca showed a response, and in this the increase was not great.

Pull in the direction of the longitudinal axis of the plant called forth a small increase of mechanical tissue in the main and lateral roots of *Helianthus annuus* and *Ricinus communis*.

Compression tension brought small increases of mechanical tissue in the stems of Fuchsia, Vinca, and Helianthus. By the same method Coleus gave no response.

The investigation, the results of which are here recorded, was carried out under the direction of Professor F. C. NEWCOMBE, to whom I wish to express my grateful thanks for kindly encouragement and helpful suggestions.

UNIVERSITY OF MICHIGAN,
ANN ARBOR, MICH.

LITERATURE CITED

BALL, O. M., **:04,** Der Einfluss von Zug auf die Ausbildung von Festungsgewebe. Jahrb. Wiss. Bot. **39**:305.

BOODLE, L. A., **:02,** On lignification of phloem in *Helianthus annuus*. Annals of Botany **16**:180.

DENNERT, E., **'87,** Anatomische Metamorphose der Blüthenstandaxen. Bot. Hefte, Forschungen aus dem Bot. Garten zu Marburg, Heft 2: 128–217. Abstract in Bot. Jahresb. **1887**[2]:647.

ELFVING, FREDR., '88, Zur Kenntniss der Krümmungserscheinungen der Pflanzen. Öfversigt af Finska Vet. Soc. Förhandlingar **30**:——. ——.

FITTING, H., :04, Weitere Untersuchungen zur Physiologie der Ranken. Jahrb. Wiss Bot. **39**:424.

GOEBEL, K., :00, Organography of plants (Eng. ed.) **1**:206.

HARTIG, R., '96, Wachsthumsuntersuchungen an Fichten. Forst-naturwiss. Zeitschr. **5**:1.

HEGLER, R., '91, reported by PFEFFER *q. v.*

KELLER, H., :04, Ueber den Einfluss von Belastung und Lage auf die Ausbildung des Gewebes in Fruchtstielen. Inaugural-Dissertation. Kiel.

KLEIN, O., '86, Beiträge zur Anatomie der Inflorescenzen. Inaugural-Dissertation. Berlin.

KNIGHT, T. A., 1803, Phil. Trans. Roy. Soc. Lond. **2**:277.

KÜSTER, E., :00, Beiträge zur Kenntniss der Gallenanatomie. Flora **87**:173.

MACDOUGAL, D. T., '96, The mechanism of curvature of tendrils. Annals of Botany **10**:373.

NEWCOMBE, F. C., '95, The regulatory formation of mechanical tissue. BOT. GAZETTE **20**:441.

PENHALLOW, D. P., '86, Mechanism of movements in Cucurbita, Vitis, and Robinia. Proc. and Trans. Roy. Soc. Canada **4**[4]:49.

PEIRCE, G. J., :03, Plant physiology 241.

PFEFFER, W., '91, Untersuchungen R. HEGLER'S über den Einfluss von Zugkräften auf die Festigkeit und die Ausbildung mechan. Gewebe in Pflanzen. Ber. kgl. Sächs. Gesellsch. Wiss. Math.-phys. Cl. **43**:638.

——, :01, Pflanzenphysiologie **2**:148.

PIETERS, A. J., '96, The influence of fruit-bearing on the development of mechanical tissue in some fruit-trees. Annals of Botany **10**:511.

REICHE, K., '87, Beiträge zur Anatomie des Inflorescenzen. Ber. Deutsch. Bot. Gesells. **5**:310–318.

RICHTER, J., '94, Ueber Reactionen der Characeen auf äussere Einflüsse. Flora **78**:419.

URSPRUNG, A., :01, Beitrag zur Erklärung des excentrischen Dickenwachsthums. Ber. Deutsch. Bot. Gesells. **14**:313.

VÖCHTING, H., :02, Zur experimentellen Anatomie. Nachricht. kgl. Gesells. Wiss. Göttingen Math.-phys. Cl. **38**:278.

VON DERSCHAU, M., '93, Der Einfluss von Kontakt und Zug auf rankende Blattstiele. Inaugural-Dissertation. Leipzig.

WIEDERSHEIM, W., :03, Ueber den Einfluss der Belastung auf die Ausbildung von Holz- und Bastkörper bei Trauerbäumen. Jahrb. Wiss. Bot. **38**:41.

WIESNER, J., '92, Untersuchungen über den Einfluss der Lage auf die Gestalt der Pflanzenorgane. Sitzb. k. Akad. Wiss. Wien. Math.-naturw. Cl. **101**[1]: 657.

WORGITZKY, '87, Vergleichende Anatomie der Ranken. Flora **69**:79.

WORTMANN, J., '87, Zur Kenntniss d. Reizbewegungen. Bot. Zeit. **45**:785.

PERIODICITY IN THE PRODUCTION OF THE SEXUAL CELLS OF *DICTYOTA DICHOTOMA*[1]

CONTRIBUTIONS FROM THE BOTANICAL LABORATORY OF THE JOHNS HOPKINS UNIVERSITY, No. 6

W. D. HOYT

(WITH TWO CHARTS)

The antheridia of *Dictyota dichotoma* (Huds.) Lamour. were described in 1855 (**1**), but the motility of the spermatozoids was not discovered until 1896 (**2**).

In 1898 WILLIAMS (**3**) stated that the sexual cells of this alga are produced in fortnightly crops bearing a definite relation to the tides, and suggested that illumination is the factor determining the time of fruiting. In an excellent paper on the cytology of the gametophytic generation (**4**) the same author added a few details to his previous statements, and in 1905 (**5**) he gave a full account of the periodicity of Dictyota on the north coast of Wales, near Bangor, and discussed the factors which may determine this behavior. He also recorded a similar periodicity in this alga at Plymouth, England. At both places the time of production of the sexual crops bears a definite relation to the spring tides. The spring tides are, of course, those of greatest range, having the highest floods and the lowest ebbs, and occur every two weeks, about the times of the new and full moons. The neap tides are those of least range, having the lowest floods and the highest ebbs, and occur between the springs. A summary of records taken at Bangor for seven years shows that at this place the sexual crops of *Dictyota dichotoma* are generally initiated several tides before the least neap, and liberated from three to five tides after the greatest spring. They thus extend through parts of two sets of spring tides.

In his discussion of the factors which may regulate the periodicity, WILLIAMS assumes that the determining factor is one that varies with the alternation of spring and neap tides, and is most marked at

[1] An abstract of this paper was presented before Section G of the A. A. A. S., New York City, December 31, 1906.

the greatest spring tides. The effect of aeration, temperature, pressure, and light is considered. The first three are deemed negligible because plants in different situations subjected to different conditions in these respects show the same behavior in fruiting. Light, then, is the remaining condition which, with the alternation of spring and neap tides, varies most for the plants of all situations, and this is believed to be the determining factor for the following reasons. (1) At Bangor the development of each crop is rapid at first, when there is comparatively little water over the plants at low tide and much light is obtained. The development is retarded with the approach of neap tides when the light is weak, and is accelerated by the following spring tides when the available light again becomes strong (*chart 1*). (2) Whether liberation shall occur on the third or fifth tide after the greatest spring tide depends on whether the preceding spring tides have been great or small, thus giving more favorable or less favorable light conditions for the rapid development of the early stages. (3) The length of time taken by any crop to pass from initiation to liberation is directly proportional to the number of days intervening between one set of spring tides and the next; in other words, to the number of days when the available light is weak. (4) During October and November the light becomes less intense at the low water of spring tides, and both initiation and liberation are delayed several tides. (5) At Plymouth, England, the crops seem to be produced wholly within one set of spring tides, and the time of liberation seems to be determined by the height of the tides during development. The light is less advantageous at the low water of spring tides, and liberation does not occur until seven to twelve tides after the greatest spring.

These facts seem to show a causal relation between the amount of available light and the time of fruiting, but a single experiment tends to make this conclusion less certain. Two sexual plants of Dictyota were brought into the laboratory in October and left undisturbed during the winter. When examined the following April, they produced three crops at fortnightly periods, although they had been removed from the alternating influence of the tides for six months. WILLIAMS therefore concludes that "periodicity of the sexual cells is an hereditary character and consequently may be expected to manifest itself in

seas and habitats where there are no tides. At the same time, the sexual cells are so responsive to changes in the amount of illumination that the time of their development in seas where there are tides is regulated by the increased illumination obtained during the low water of spring tides" (**5,** p. 548).

During a stay at the laboratory of the Bureau of Fisheries at Beaufort, N. C., the past summer, a record was kept of the fruiting of the sexual plants of *Dictyota dichotoma*, together with observations on the tides and the conditions of growth. The following facts were observed. (1) The sexual cells were produced in regular periodic crops. (2) The time of the production of these crops bore a definite relation to the tides. (3) The crops were borne at monthly instead of fortnightly intervals, appearing only at alternate spring tides. (4) Rudiments of sexual organs were first observed on the day of, or the day before, the greatest spring tide, instead of a few days before the least neap as at Bangor. (5) The time taken for the development of an entire crop was about eight or nine days, instead of twelve to seventeen days. (6) General liberation occurred six days after the greatest spring tide, instead of two to five days. (7) Differences in the height of different sets of spring tides had no effect on the time of liberation or the time taken for the development of an entire crop. Thus, the August crop was liberated six days after the greatest spring tide, the preceding ebb tides having been the lowest observed during the summer. The October crop was liberated at the same interval, although the tides for nearly a month previous had been exceptionally high at both ebb and flood. (8) Differences in the time intervening between one set of spring tides and the next had no effect on the time of initiation of rudiments or of liberation of gametes. Although the number of days between one spring tide and the next varied from twelve to eighteen, rudiments were always first observed about the day of the greatest tide, and liberation always occurred six days after the greatest tide of each alternate set of springs.

A comparison of the record of a single crop at Beaufort, beginning with the day when rudiments of sexual organs were first observed, with a similar record for a crop on the coast of Wales, will best illustrate the difference in development (*charts 1* and *2*). This record is followed in each case with male plants, and the numbers given are

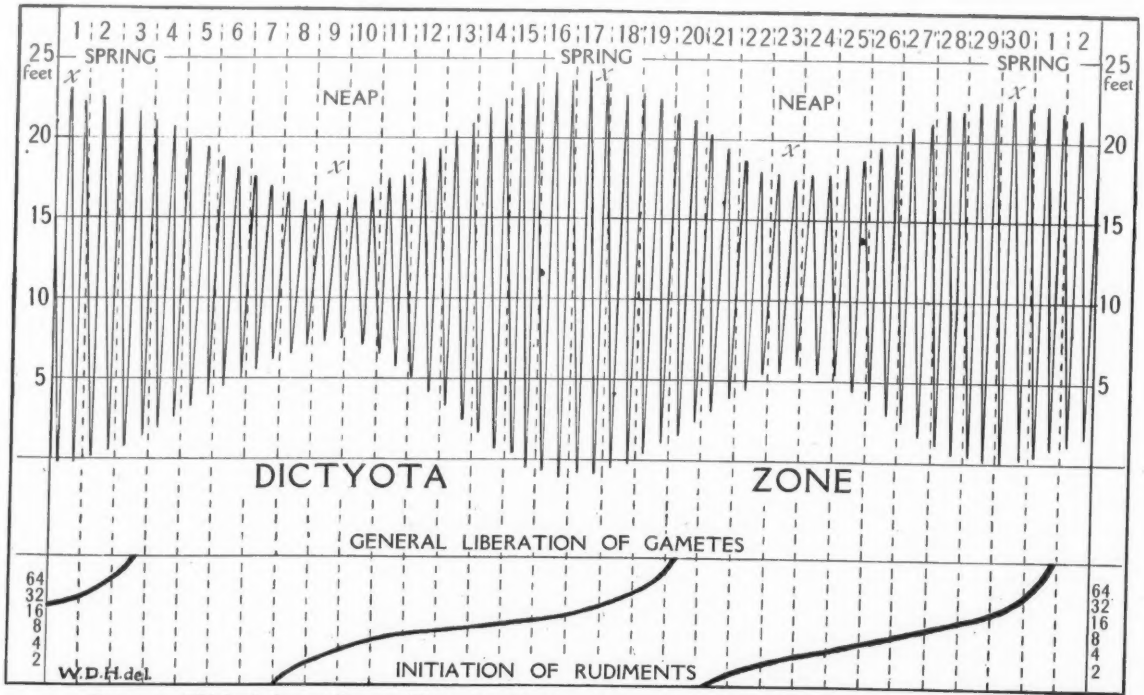


CHART 1.—Tidal relations at Bangor, Wales, for thirty-two days, showing great tides and two crops of Dictyota.

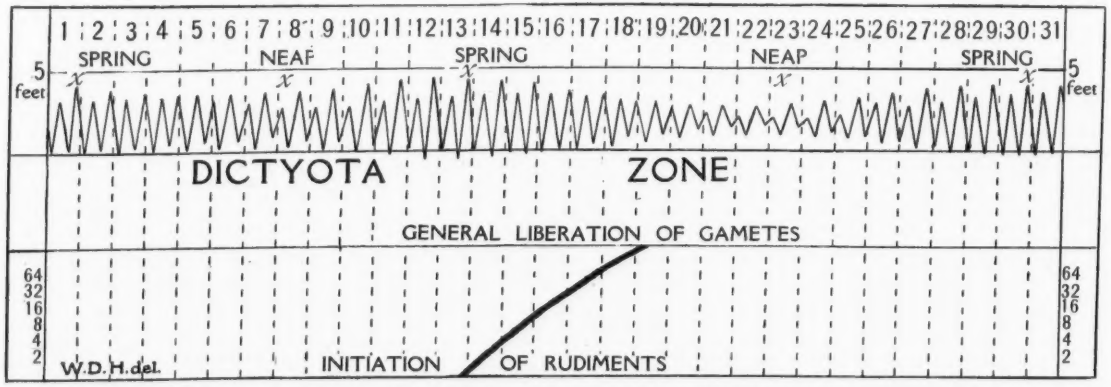


CHART 2.—Tidal relations at Beaufort, N. C., for thirty-one days, showing slight tides and only one crop of Dictyota.

The tide records are taken from the Tide Tables for 1906 of the U. S. Coast and Geodetic Survey. While wind and other factors may cause any tide to vary from the heights given at either Bangor or Beaufort, the figures show the general course of the rise and fall at the two places. The curves showing the development of Dictyota at Bangor are adapted from WILLIAMS (**5**, p. 559). The two charts are drawn to the same scale. The zig-zag lines show the rise and fall of the tide and the heights of the water in relation to the Dictyota zone. The curved lines show the development of the sexual crops of Dictyota for the respective periods with their relations to the tides. The numbers opposite the crop curves indicate the number of cells seen in the surface-view of each antheridium.

those of cells seen in the surface-view of each antheridum. The actual number of cells in each antheridium is much greater. These show as follows:

	BEAUFORT	BANGOR
1st day.....	Undivided rudiments	Undivided rudiments
3d day.....	8–16 cells	" "
4th day.....	32–64 cells	" "
5th day.....	64 cells	" "
6th day.....	General liberation	
7th day.....	Liberation from belated sori	2–4 cells
10th day.....		Many 64 cells
12th day.....		General liberation
13th day.....		Liberation from belated sori.

In addition to this difference is the fact that the records taken make it probable that every crop produced during the fruiting season at Beaufort was similar in development to the one described, while at Bangor there is considerable difference in the development of different crops. The cause of these differences in the fruiting of the plants on our coast and on the coasts of Wales and England is not apparent. A comparison of the tides at the different localities, however, is of interest in this connection (**6**) (*charts 1* and *2*).

The average range of the tide is: near Bangor, Wales, 17.9 feet; at Plymouth, England, 11.5 feet; at Beaufort, N. C., 2.8 feet. The average difference in the height of low water at spring and neap tides is: near Bangor, Wales, about 5.7 feet; at Plymouth, England, about 3.4 feet; at Beaufort, N. C., 0.5 foot. We are still unable to say whether these differences will explain the difference in behavior, or whether this is due to some other, possibly ancestral, cause.

It is possible that the Dictyota occurring at Beaufort is a different species from that found at Bangor or Plymouth. To determine this, a specimen was sent to Mr. FRANK S. COLLINS of Malden, Massachusetts, who verified the identification, referring it to *D. dichotoma*. In spite of the morphological resemblance, however, it is possible that the Beaufort form is a different physiological species, and this can be determined only by means of cultures. The final test can be made only by growing some of the Bangor plants at Beaufort and *vice versa*. It is hoped that this can be done at some future time.

The explanation of this periodicity is not apparent. Although the

behavior of this alga at Bangor and Plymouth may be explained by the assumption that illumination is the determining factor, the facts observed at Beaufort indicate that for the plants of this region, at least, some other explanation must be sought. That the time of fruiting is determined to some extent by the tides is indicated by the very exact relation which this bears to the tides. That illumination is not the determining factor is indicated by the facts that fruiting occurred only on alternate spring tides, that differences in the amount of light as determined by the state of the weather and the heights of different sets of spring tides had no effect on the time of fruiting, and that the differences in light conditions to which individual plants are subjected are greater than those differences to which all the plants are subjected because of differences in the height of water at spring and neap tides.

As was mentioned above, the average difference in the height of low water at Beaufort at spring and neap tides is only 0.5 foot. As the difference in the depths at which individual plants grow is at least six times as great as this, the difference in the amounts of light received by different plants at any instant is greater than the differences in the amounts of light received by any one plant at low water of spring tide and at low water of neap tide. And yet all the sexual plants observed in all situations fruited at the same time. It may be urged that the sexual plants are sensitive, not to the actual amount of light, but to the maximum intensity, and that this occurs at the time of the spring tides for the plants of all situations. But the same reasoning applies to all the other factors which are influenced by the tides— such as aeration, pressure, etc.— so that there is no more reason on this ground to ascribe the behavior to the light than to any one of the other factors.

One observation is interesting in this connection. A female plant was brought into the laboratory August 11 and placed in a covered jar of sea-water near a window. As is often the case when *Dictyota dichotoma* is subjected to unfavorable conditions, proliferations were formed from the margin of the thallus. When examined October 6, most of the plant had died, but several proliferations were still alive, and these showed sori of uniform age only slightly less advanced than those on plants growing in the harbor. In this case

the entire plant had been removed from alternating conditions (except those of day and night) for nearly two months, and the sori were borne on proliferations produced while the plant was in the laboratory, consequently on parts of the thallus whch had never been subjected to alternating conditions. This result is similar to one obtained by WILLIAMS (**5**, p. 547), but goes one step farther in showing that the periodicity is transmitted to new structures formed from the original plant, even when these are not subjected to alternating conditions. These proliferations were, of course, produced by the protoplasm of the parent plant; it still remains to be seen whether the periodic habit can be transmitted through the protoplasm of the egg.

A few observations were made at Beaufort in the summer of 1905, but no satisfactory records were obtained. The observations made, however, indicate that the behavior of the sexual plants was like that observed during the past summer.

Many specimens of several species of Dictyota have been obtained from two localities in Jamaica. Among these are four sexual plants—two male and two female—collected by the author at Port Antonio, April 13, 1906, and eight sexual plants—two male and six female—collected by Mr. I. F. LEWIS at Port Morant, July 16, 1906. Although this material is too scanty to warrant a conclusion, it is interesting to note the direction in which the evidence points.

The specimens from Port Antonio have all the sori of about the same age, and at the same stage of development that would be expected for plants of Dictyota at Beaufort, N. C., on the same day. In the specimens from Port Morant, the male plants have all the sori of the same age, while all the female plants have sori of two ages, one set being mature, and the other being young and at a stage corresponding to that of the antheridial sori on the male plants. These sori of two ages probably represent two crops of eggs, the older of which was not shed before the younger one was produced. The age of the older crop cannot be stated with certainty, but the age of the younger crop of eggs and of the antheridial sori does not agree with the age of sori on plants collected by the author on the same day at Beaufort. They seem at about the stage of development, however, that would be expected for Dictyota at Bangor on this day. These facts indicate that, on the coast of Jamaica also, Dictyota shows periodicity in the production of sexual cells. As there are practically no tides on this

coast (about six inches), this condition, if true, supports WILLIAMS' conclusion that "the periodicity of the sexual cells is an hereditary character and consequently may be expected to manifest itself in seas and habitats where there are no tides."

As the Jamaican specimens of Dictyota belong to more than one species, the facts indicate the probability that periodicity obtains throughout the genus. The apparent correspondence in the time of fruiting of the Port Antonio specimens with those of Beaufort, and of the Port Morant specimens with those of Bangor may be only a coincidence. It is certain, however, that the time of fruiting of the Port Morant specimens did not coincide with that of Dictyota at Beaufort. Evidently we need more observations before we can draw general conclusions or suggest explanations of the facts already observed.

The author is able to verify WILLIAMS' statements that light is not necessary for the escape of the sexual cells of *Dictyota dichotoma*, and that the tetrasporic plants show no periodicity.

From a single set of observations, WILLIAMS gives evidence of periodicity in "Haliseris" and suggests by inference the possibility of its occurrence throughout the Dictyotaceae. A species of Padina, probably *P. Durvillaei* Bory, is abundant at Beaufort in the same situations with Dictyota. Numerous male plants were found and these showed no evidence of periodicity, sori of all ages occurring on the same plant. It seems, therefore, that periodicity is not characteristic of all the Dictyotaceae. All the sexual plants of Padina which were examined bore only antheridia and produced these on both sides of the thallus, differing in these respects from the printed descriptions. The antheridia were numerous, being borne in sori in wide concentric rows which appeared white to the naked eye, and the sori were usually produced in regular acropetal succession.

The author expects to continue this work, but, believing the present data to be insufficient to explain this periodicity, gives the results already obtained with the hope of inducing other botanists who are favorably situated to begin a study of this form. It seems that only by observations of the fruiting and careful comparison of the conditions at a number of places for a considerable period of time can we hope to understand this striking phenomenon.

Indebtedness is gratefully acknowledged to Hon. GEORGE M. BOWERS, U. S. Fish Commissioner, for the privilege of working in

the Fisheries Laboratory at Beaufort, N. C.; to Mr. H. D. ALLER, Acting Director of the Fisheries Laboratory at Beaufort, N. C., for many courtesies extended during this investigation; to Mr. FRANK S. COLLINS, Malden, Massachusetts, for verifying the determination of the species of Dictyota occurring at Beaufort; to Dr. MARSHALL A. HOWE, New York Botanical Garden, for information concerning Padina; to Mr. I. F. LEWIS, Johns Hopkins University, for specimens of Dictyota from Port Morant, Jamaica; and to Professor D. S. JOHNSON, Johns Hopkins University, for helpful criticisms and suggestions.

CONCLUSIONS

1. As on the coast of Wales and England, *Dictyota dichotoma* at Beaufort, N. C., produced its sexual cells at regular intervals, bearing a definite relation to the tides.

2. The time of production of these crops, however, differs from that on the coasts of Wales and England, the crops being borne at monthly instead of fortnightly intervals.

3. The assumption that light is the sole factor determining the time of fruiting does not hold for the plants of *Dictyota dichotoma* growing at Beaufort.

4. Specimens of Dictyota from Jamaica indicate that there also the sexual cells are produced in periodic crops, and that periodicity may obtain throughout the genus. The time of fruiting, however, at least in some cases, is different from that of Dictyota at Beaufort.

5. Periodicity in the production of the sexual cells is not universal among the Dictyotaceae. A species of Padina, probably *P. Durvillaei* Bory, bears antheridial sori of all ages on the same plant.

JOHNS HOPKINS UNIVERSITY
BALTIMORE

LITERATURE CITED

1. THURET, G., Recherches sur la fécondation des Fucacées et les anthéridies des Algues. Ann. Sc. Nat. Bot. IV. **3**:5–28. *pls. 2–4.* 1855.
2. WILLIAMS, J. LLOYD, The antherozoids of Dictyota and Taonia. Annals of Botany **11**:545–553. *pl. 25.* 1897.
3. ———, Reproduction in *Dictyota dichotoma*. *Ibid.* **12**:559–560. 1898.
4. ———, Studies in the Dictyotaceae, II. The cytology of the gametophyte generation. *Ibid.* **18**:183–204. *pls. 12–14.* 1904.
5. ———, Studies in the Dictyotaceae, III. The periodicity of the sexual cells in *Dictyota dichotoma*. *Ibid.* **19**:531–560. 1905.
6. U. S. Coast and Geodetic Survey, Washington, Tide Tables for the year 1906.

THE FUNCTION OF INVERTASE IN THE FORMATION OF CANE AND INVERT SUGAR DATES

A. E. VINSON

The chemical character of the ovulary of the date, *Phoenix dactylifera*, has seldom been studied, although the seed has long furnished a convenient and favorite material for the most diverse researches. Published analyses with few exceptions have been made by the usual WEENDE methods and consequently give no idea of the real chemical nature of the fruit. A French analysis[1] made before 1867 mentions

	Per cent.
Water	43.6
Albuminoid and pectin bodies	2.9
Gallic acid and glucose	47.9
Inulin	trace
Fat	0.4
Cellulose	1.9
Mineral matter	3.3

a trace of inulin, but otherwise is of little significance.

SELNY[2] seemed to strengthen the prevalent view, that dates contain little or no cane sugar, by the analysis of a number of Mesopotamian dates which contained dextrose (invert sugar) only. In reply to SELNY'S paper, however, LINDET[3] points out that a sample of Tunis dates—probably Deglet Noors which occur on the Paris market—analyzed by him in 1891 contains 23 per cent. of glucose (invert sugar) and 38 per cent. of cane sugar. This is the first mention of a cane sugar date that I have found, aside from recent comparative analyses, made at this station, of Arizona-grown dates from trees imported from all the date-growing regions of the world by the U. S. Department of Agriculture and placed in the Cooperative Date Orchard at Tempe, Arizona.

LINDET cautions against generalizing from a few analyses when they concern plants and fruits, for the absolute and relative proportions of sugars will vary with climate, condition of season, degree of maturity, etc. In this paper I intend to show that other factors,

[1] Recueil de Mémoires de Médicine de Chirugie et de Pharmacie Militaires.

[2] Journal de la distillerie française. 1895.

[3] *Ibid.* 118. 1895 [abstract Chem. Zeit. **20**;898].

especially the presence of invertase, and probably limitations in the distribution of the same, are more potent in determining the relative proportion of the sugars than the factors mentioned by LINDET. According to observations on the date, it seems that fruits of the same species but of different chemical nature are true chemical mutants, determined by the plant itself rather than by its environment. Further investigations may reveal cane sugar varieties of what BUIGNET[4] considered inverts ugar fruits, as grapes, currants, and figs, or invert varieties, among the partially cane sugar fruits, bananas, apricots, peaches, plums, apples, and pears.

SLADE,[5] basing a classification on the analyses of varieties, from the Tempe orchard, of various native seedlings and of native fruits from Mexico, divided dates into two main classes: cane sugar dates, embracing the Deglet Noor, and M'Kentichi Degla; and invert sugar dates, embracing Rhars, native seedlings, Mexican dates, and most others. It is possible to have partial cane sugar dates, and such do exist, as I shall point out later. While SLADE'S classification is correct for mature and cured dates, nevertheless all dates are decidedly of the cane sugar type at some time of their life-history.[6] This fact gave the first clue to the influence of invertase in determining the saccharine character of the date and probably of most other fruits.

It appears probable that the carbohydrates may enter the fruit as cane sugar, for nearly all fruits, either cane or invert sugar, show an appreciable percentage of cane sugar at the period of maximum accumulation of dry matter. This is often very inconsiderable, as we see in KEIM'S[7] analysis of ripening cherries, and may not be detected at all, as in the ripening persimmon.[8] Even in these cases more cane sugar would be found if special precautions were taken to destroy the invertase immediately after removing from the tree. The cane sugar of the date vanishes very rapidly in the invert varieties. MIERAN[9]

[4] Compt. Rend. **51**:894. 1860; through Bull. 94, Bur. of Chem., U. S. Dept. Agric.

[5] All notes on the unfinished work with dates of H. B. SLADE (died June 5, 1905) were turned over to the writer and acknowledgment is made in this paper whenever material from that source has been used.

[6] Ann. Rep. Arizona Agr. Exp. Sta. **17**:164, 165.

[7] Zeit. Anal. Chem. **30**:401. 1891.

[8] BIGELOW, GORE, and HOWARD. Jour. Am. Chem. Soc. **28**:688.

[9] Chem. Zeit. **56**:1003, 1021, 1283. 1893.

found also that banana pulp not only reduced its own cane sugar rapidly, but could invert large amounts of added cane sugar. BAILEY,[10] however, states that he failed to find any enzymic action in the ripening of the banana, but his figures show a dropping-off of cane sugar after the yellow-brown stage.

In a set of tests for invertase with very green, yellow, and black-ripe bananas, made in this laboratory, a feeble inverting power at room temperature was found in the two latter conditions, but not at all comparable with that of an invert sugar date under like conditions. It is possible that cane and invert sugar bananas may be found. In the banana, however, the reserve material in the fruit itself is largely starch and is finally converted into cane sugar, either directly or by way of maltose. Nevertheless, it would seem that some cane sugar, as such, may come into the banana ripened on the tree, for both BUIGNET[11] and RICCIARDI[12] agree that when ripened naturally this fruit contains more cane sugar and less invert sugar than when ripened artificially. Substantially the same is true with the cane sugar date. It is not untenable, however, that some other soluble carbohydrate may enter the fruit and be rapidly synthesized to cane sugar, for BROWN and MORRIS[13] have shown that the excised barley embryo, cultivated on maltose solution, formed cane sugar very rapidly by the "action of the living embryo cell." They found also that living embryos did not synthesize cane sugar from glucose. This difficulty is not insurmountable, for HILL[14] demonstrated the reversible nature of enzymic action by synthesizing maltose from glucose in very dilute solution by the aid of maltase. The maltose formed was later found to be isomaltose,[15] but that does not necessarily mean that, under cell conditions, true maltose would not be formed. The reverse action of enzymes has been shown to be influenced, at least with regard to speed, by the presence of a third body. Thus ethyl-butyrate is formed more rapidly by lipase in the presence of lecithin.[16]

[10] Jour. Biol. Chem. **1**:355. 1906.

[11] Compt. Rend. **49**:276–278. 1859; through Bull. 94, Bur. of Chem.

[12] Compt. Rend. **95**:393. 1882; *ibid.*

[13] Jour. Lond. Chem. Soc. **57**:458 (517). 1890.

[14] Jour. Lond. Chem. Soc. **73**:634. 1898.

[15] Through LOEB, Dynamics of living matter 11. New York 1906.

[16] HEWLETT, *ibid.* p. 10.

That cane sugar may find its way directly into the fruit would seem probable, moreover, since it is one of the most diffusible carbohydrates, and BROWN and MORRIS[17] believe it the primary carbohydrate synthesized by the chloroplasts. Cane sugar, however, is not suited to nourish the protoplasm. If injected directly into the blood of animals, BERNARD[18] has shown it to be eliminated unchanged by the kidneys, and to be inverted in the beet root before being used. Glucose appears in the beet root and can be traced up the stem, but not so with cane sugar. FORBES[19] finds the same true with canaigre, *Rumex hymenosepalus*. The small amount of cane sugar contained in the dormant root suddenly decreases when the root begins to send up a stalk. The much larger amount of starch is similarly affected. As is well known, the moving carbohydrate of the maple is nearly pure cane sugar. Plant leaves are also known to contain invertase in conjunction with cane sugar. BROWN and MORRIS consider the entire amount of cane sugar to be hydrolyzed, first for the nutrition of the tissues, and then any excess to be resynthesized into starch for future use, the hydrolytic product of this starch being maltose. It appears thus that either cane sugar, invert sugar, or maltose has the opportunity of leaving the leaf. SAPOSCHNIKOFF[20] says the form in which the carbohydrate leaves the leaf is unknown, but is probably glucose.

It has been established, on the other hand, that the existence of starch in the tuber of the potato,[21] in maize,[22] and in wheat[23] depends on the previous existence of cane sugar in the juice of these plants. KEIM,[24] in HILGER'S laboratory, found cane sugar to accumulate in the leaves of the cherry and starch in the fruit stems during the growing stage, both of which disappear at the period of maximum ripening, when a small amount of very transient cane sugar is found in the

[17] A contribution to the chemistry and physiology of foliage leaves. Jour. Lond. Chem. Soc. **63**:604. 1893.

[18] GREEN, The soluble ferments 110. Cambridge 1899.

[19] Unpublished papers.

[20] Bildung und Wanderung der Kohlenhydrate in der Laubblättern. Ber. Deutsch. Bot. Gesells. **8**:233. 1890.

[21] GIRARD, Compt. Rend. **108**:602. 1889.

[22] ZEPLEY, Compt. Rend. **94**:1033. 1882.

[23] BALLAND, Compt. Rend. **106**:1610. 1888.

[24] *Loc. cit.*

fruit. They explained this erroneously by considering that the acidity of the leaf was insufficient to invert the cane sugar, and only after it reached the acid fruit could such inversion take place. The occurrence of some cane sugar in the earliest stages of growth of the cherry, and its subsequent disappearance, they also attribute to a lack of acid. BUIGNET[25] attempts to explain the high cane sugar content of some strawberries in much the same way, on the hypothesis that the sugar and acid exist in different cells, and that in the watery varieties diffusion and consequently inversion take place more rapidly than in drier berries. In a later paper[26] he concludes that acidity has nothing to do with the inversion, but that it is probably the work of a "nitrogenous ferment." In the date acidity has nothing to do with inversion, for the cane sugar dates are usually the more acid. Neither does the high acidity of the orange appear to determine inversion, for here the cane sugar increases during ripening, while the invert sugar remains nearly constant. This BERTHELOT and BUIGNET[27] think is especially remarkable, since the green fruit contains no starch from which to derive the cane sugar. The phenomenon, however, is almost identical with that of the cane sugar date and just what would be expected of any fruit having similar invertase relations. The accumulation of starch in the stem of fruits which contain none appears to be quite common and has been observed in the grape.[28] Whether or not this is the case with the date has not been determined.

While the observed fact that cane sugar accumulates at the time of maximum ripening in nearly all fruits, even the pea[29] and cucurbits,[30] points very strongly to that sugar as the original carbohydrate to enter the fruit, one point militates most powerfully against such a hypothesis; the partial osmotic pressure of cane sugar within the date would stop flow in that direction long before the high observed

[25] Résumé, Compt. Rend. **49**:276–278. 1859; through Bull. 94, Bur. of Chem.

[26] Compt. Rend. **51**:894. 1860; *ibid.*

[27] Compt. Rend. **51**:1094. 1860; *ibid.*

[28] FAMINTZIN, Ann. Oenol. **2**:242. 1871; and HILGER, Landw. Vers. Station **17**:245. 1874; through KEIM, *loc. cit.*

[29] SCHWARZ AND RIECHEN, Zeits. Unters. Nahr. Genuss. **1904**:550; and FRERICHS AND RODENBERG, Arch. Pharm. **243**:276. 1905.

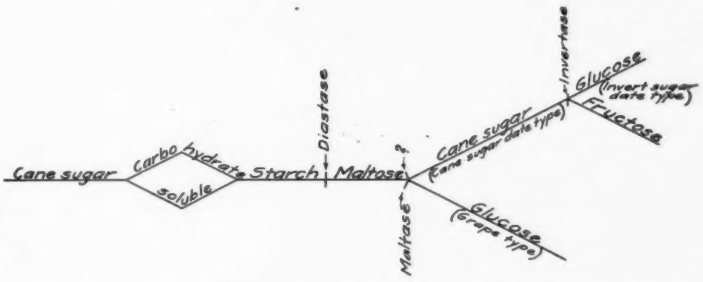
[30] LECLERC DU SABLON, Compt. Rend. **140**:320, 321. 1905.

percentages of cane sugar could be approached. The same is true also for glucose and fructose, for on the inversion of the cane sugar present they appear in approximately molecular proportions as determined by BROWNE'S[31] method. Occasional samples vary considerably from this relation, giving sometimes a large excess of fructose, sometimes of glucose. This may be explained in part by a number of possibilities. The difficulties of technic in taking consecutive representative samples of such material as pulped date must be taken into consideration because data from two different samples enter the BROWNE formula. An excess of fructose may be accounted for by the hydrolysis of inulin. SLADE found inulase in some dates but has left no record of having found inulin. Neither inulin nor inulase was found by the writer in a sample examined in that regard. An excess of fructose over glucose might also originate in the preferential use of glucose by the tissues, as is known often to be the case. An excess of glucose might come from maltose and SLADE observed maltase, but I have not yet examined the date for that enzyme. Here again an excess of glucose might be consumed by the tissues, leaving nearly pure invert sugar. The relation between fructose and glucose in other fruits has never been worked out, but it appears that in the case of the date nearly all the sugar is cane sugar or a derivative of cane sugar.

Times thus undoubtedly occur with every individual when the partial osmotic pressure of these three sugars is approximately equal; nevertheless, accumulation of total sugars goes on rapidly. The date, then, as a species at least, must be prepared to pass in carbohydrate against a relatively high osmotic pressure of cane sugar, glucose, or fructose, either singly or simultaneously. Unless we choose to hold that the intercellular threads of living protoplasm pass along colloids and crystalloids against osmotic pressure, we are forced to seek some likely soluble carbohydrate against which there exists no considerable pressure. This place seems to be filled by maltose. So far as I am aware, neither the presence nor the absence of maltose has been demonstrated in the growing date. We should never expect to find any great amount, and it might be so transient as to escape detection entirely.

[31] Bur. of Chem. Bull. 90: 10; also Jour. Am. Chem. Soc. **28**: 439. 1906.

The following scheme for the translocation of sugars from stems and leaves to fruit seems then to be in accord with all known facts and contradicted by none. In the early stages cane sugar or mixed sugars move into the fruit until osmotic equilibrium is reached. After that, excess of cane sugar may be stored as starch within the fruit, as in the case of the banana and apple, thus diminishing the osmotic pressure for that sugar; or a part may be reduced to invert sugar, farther reducing the cane sugar pressure. On ripening, the starch is again transformed to soluble sugars. In those cases where no starch occurs in the fruit itself, but in the stem, the latter is probably a laboratory and not an ordinary storage tissue. The plant would scarcely have found it advantageous to thrust storage duties on the



stem when the fruit was fully capable and destined to receive the same material later. It seems more probable that after osmotic equilibrium is reached between the fruit and sap, those sugars against which there is osmotic pressure would be changed to starch at the threshold, and this starch in turn hydrolized by an amylase into maltose. Maltose, against which there is little or no osmotic pressure, would enter the fruit and there be split up into glucose or rearranged into cane sugar, which would be inverted where it comes into contact with invertase. Probably all these reactions take place to a greater or less degree in any ripening fruit, but the predominance of one or the other leads to a special type. If the main reaction were maltose to glucose, fruits of the grape type would result. If maltase secretion were suppressed, the maltose would follow the transformation it takes in fruits of the date type.

It is true that no catalytic outside the living cell is known which will transform maltose into cane sugar, but the cell is known to do so and the catalytic will probably be discovered. The transformation of starch to cane sugar seems to be established for the banana and apple, but here again no catalytic is known that will cause the transformation, although many, and some of organic origin, transform it into maltose. BROWN and MORRIS, moreover, have shown maltose to be the final product of starch hydrolysis in the leaf. Thus it seems probable that in these cases starch changes to cane sugar through maltose. It is also probable that the speed of transformation, maltose to sucrose, is very considerable, since BIGELOW and GORE[32] find the curve representing the increase of cane sugar in a ripening apple to be nearly the reverse of that representing the decrease in starch.

An examination of the accompanying table will reveal the chief points of interest in the development of the date, and also the divergence between the cane and invert sugar varieties. The cane sugar date is represented by the fruits of the Deglet Noor[33] from palms imported from the oasis of French Algeria in 1900. The invert sugar date is from a seedling palm of excellent quality growing upon the university campus and immediately accessible from the laboratory.

It seems that any attempt to interpret a series of date analyses, made at different stages of growth, by reducing them to the dry basis, can give only a partial idea of what is actually taking place. Water has as much to do with the changes as cane sugar or invert sugar. A date having 20 per cent. of dry matter may change in a few days to one of 60 per cent. in three ways: by the loss of water through transpiration with decrease in weight; by the addition of dry matter without loss of water, possibly some gain, and increase in weight; or by the addition of dry matter with loss of water and little or no change in weight. In the case of the cherry, KEIM has noted that the period of maximum increase in percentage of dry matter in the fruit is parallel with that of maximum increase in weight. In the peach[34] the increase in solids is fairly proportional to the increase in water. With the date there is a more or less parallel increase in percentage of dry matter and

[32] Bull. 94, Bur. of Chem., U. S. Dept. Agric.

[33] SWINGLE, Bur. Plant Ind., U. S. Dept. Agric. Bull. 53:33.

[34] BIGELOW and GORE, Bur. of Chem., U. S. Dept. Agric. Bull. 97:12.

CANE SUGAR DATE; DEGLET NOOR—TEMPE, ARIZ.

Date	Condition of sample	Condition of bunch	Av. wt. grams	Av. wt. seeds	Per cent. seeds	Per cent. dry matter	Per cent. cane sugar	Per cent. fructose	Per cent. glucose
Sept. 18, 1906	Pea size	Belated	1.15	0.145	1.25	17.66	1.99	2.62	3.34
" 18, 1906	Green, about half grown	"	5.02	0.572	11.39	17.41	0.62	3.82	3.27
" 18, 1906	Slightly yellow	"	6.96	0.905	13.01	20.15	5.14	2.90	3.20
Oct. 5, 1906	Green, half grown	"	6.66	0.705	10.58	17.22	1.48	2.84	4.17
" 5, 1906	Green, yellow tinge	"	8.22	0.968	11.77	18.22	3.78	2.06	3.76
" 5, 1906	Red	Some slightly ripened	9.98	1.079	10.82	35.34	15.62	3.92	4.39
Sept. 7, 1906	Slightly turned green to red	Many green dates	6.57	0.992	15.10	23.59	5.05	3.09	3.97
" 7, 1906	Change more marked	Same bunch	6.40	0.794	12.41	30.24	13.86	2.89	3.46
Oct. 17, 1906	Bright red	None ripe	7.19	0.911	12.66	29.71	13.10	1.83	2.96
" 2, 1905	Reddish yellow	Some soft on end	8.84	0.636	7.20	25.56	12.57	2.93	2.94
" 31, 1905	Red, stored 5 days	A few had ripened	8.91	0.705	7.92	47.20	31.61	3.36	3.49
" 26, 1905	Red, considerable yellow	Same bunch	8.45	0.638	7.55	36.89	21.62	2.55	2.79
" 26, 1905	Slightly spotted	" "	8.92	0.671	7.33	53.45	34.20	5.26	5.40
" 26, 1905	About one-third soft	" "	8.31	0.604	7.27	56.29	31.74	7.42	8.09
Nov. 27, 1905	Slightly ripened	Some softening at stem end	8.53	0.679	7.96	59.69	36.79	5.65	5.57
" 27, 1905	Apparently fully ripe	Same bunch	9.06	0.632	6.98	62.65	33.07	9.69	9.86
" 31, 1905	Art. ripened 30 hours	" "	8.96	0.676	7.55	63.60	25.00	12.39	14.13
" 31, 1905	Art. ripened 5 days from red	" "	7.48	0.639	8.54	61.64	21.09	15.10	14.12
" 31, 1905	Same apparently inferior	" "	6.97	0.637	9.14	62.02	27.18	12.54	12.11
" 6, 1905	Art. ripened	" " as Oct. 31, 1905	7.48	0.629	8.42	57.82	24.81	11.89	12.51
Oct. 10, 1906	One-half to two-thirds ripe after 5 days ripening by solar heat	" " as Oct. 5, No. 6, above	9.00	0.732	8.13	62.40	37.79	7.19	6.60
Nov. 13, 1905	Ripe on tree		7.32	0.572	7.83	69.98	38.84	9.90	10.08
" 21, 1906	Ripe on tree		7.26	0.691	9.52	74.03	41.51	8.20	8.31
" 21, 1906	Art. ripened, stored 21 days		6.31	0.716	11.36	69.31	22.09	13.41	14.83
Dec. 4 , 1906	Ripe on tree after frost		8.19	0.643	8.41	73.20	44.71	7.74	7.47

CANE SUGAR DATE; DEGLET NOOR—HEBER, CALIFORNIA

Nov. 14, 1906	Ripe on tree		9.59	0.890	7.69	77.88	40.55	10.40	10.53
Dec. 10, 1906	Finished in incubator		10.54	0.788	7.47	73.69	38.74	11.20	11.28

INVERT SUGAR DATE; SEEDLING—CAMPUS, TUCSON, ARIZ.

Sept. 7, 1906	Very green	Like sample	10.26	1.215	11.83	15.87	0.00	2.11	4.47
Oct. 3, 1906	Yellow	Like sample	10.67	1.120	10.47	31.72	7.95	8.01	9.90
" 10, 1906	Yellow after cold week	Not maturing well	11.26	1.084	9.63	31.48	4.59	9.01	6.60
" 24, 1906	Yellow, ripe in spots	Ripening slowly	12.37	0.903	7.31	51.33	15.02	12.95	11.50
" 4, 1905	Partly ripe, softened slightly	A few ripe	12.18	.....	.....	45.07	11.56	13.89	13.46
" 16, 1905	Partly brown	Ripening rapidly	11.58	0.767	7.58	51.37	10.01	16.81	15.90
" 16, 1905	Ripe, not overripe	Ripening rapidly	8.77	0.907	10.19	52.36	6.18	21.92	20.08
" 24, 1906	Ripe, still light brown	Ripening slowly	12.07	0.907	7.51	56.14	6.76	16.67	15.70
Nov. 6, 1906	Ripe, stored 14 days		10.07	0.927	9.21	55.29	0.28	23.87	24.91
" 14, 1906	Ripe, stored 1 week		9.34	0.767	8.21	57.99	1.42	25.05	24.25

in weight (or size) till something like 20 per cent. of dry matter is present. Growth, so far as size is concerned, has then about reached its limit, but accumulation of dry matter in the form of sugar now takes place more rapidly, and in a relatively short time the dry matter rises from 20 or 25 per cent. to nearly 60 per cent. During this time there appears to be little or no further increase in weight. The rational interpretation then is that water is replaced by sugar. Curing again increases the dry matter up to 70 or even 85 per cent., but this change is purely a loss of water. These observations are further confirmed by purely practical ones. It may be observed that the individual dates on a bunch develop similarly throughout; the ones near the tips of the sprays remaining always somewhat smaller. At a certain period the bunch as a whole appears much the same and individuals begin ripening, but it may be a month or more before others on the same bunch, even on the same sprays, are ripe. The same thing is observed in artificial ripening experiments. Two sprays from the same bunch, and looking very much alike, will ripen under artificial conditions very differently. Some speedily develop into a plump, luscious fruit, while others dwindle away and finally furnish a thin skin of poor-quality flesh over an apparently normal seed. The seed seems to mature before marked changes in the ovulary begin. The fact that increase in dry matter takes place after the apparent maturity of the fruit must lie at the foundation of all economic attempts at artificial ripening. Any plans which ignore this will necessarily prove futile. The ripening process in the date, unlike that in the banana, is essentially one of addition and not of transformation. By reducing results to the dry basis, the very important economic as well as scientifically interesting observations made above would be entirely lost sight of. Furthermore, it would magnify any errors of technic from two to six times or more.

These objections cannot be raised, in like degree at least, to the method of expressing results by reducing percentages to absolute weight per date of each constituent at the several periods of development. It is evident, nevertheless, that this method also can give only a more or less distorted view, because it is practically impossible to select samples with any degree of assurance that they were of the same composition and weight as the previous sample at the time it was

taken. It seems more rational to consider the composition of each sample as we find it, together with its apparent condition of ripeness, the average weight of the individual fruits, the average weight and percentage of seeds, and finally the general relation which the individual fruits forming the sample seem to bear to the whole. By reduction to any other basis, some of these points, especially those involving personal equation in the greatest degree, are masked but not equalized.

Study of the analyses reveals a marked similarity in the composition of the two varieties up to the time of maturity in size. The Deglet Noor shows an inclination toward cane sugar even in the early stages, but from this point on it gains chiefly in cane sugar until ripeness is approached, when some inversion takes place. The amount of this inversion seems to be influenced largely by the temperature to which the ripening date is subjected. Under normal conditions, 20 to 25 per cent. of invert sugar is formed; but under the conditions necessary for artificial ripening, 45 to 50° C for several days, a much larger proportion is inverted. The sample ripened on the tree after frost shows less inversion. The invert sugar date shows an increase in invert sugar parallel to the increase in dry matter. At the period of maximum ripening, when dry matter is accumulating very rapidly, cane sugar appears in considerable quantities. This I attribute to the formation of cane sugar at a greater rate than the invertase is capable of inverting it. The same is also undoubtedly true with other invert sugar fruits, their sugar passing through cane sugar which is at times formed more rapidly than inverted. Many varieties of dates have been examined in this respect, and cane sugar is always observed to accumulate just before the date softens. At the time of softening the invertase, which before this cannot be dissolved by water or glycerin, is now readily extracted by these solvents. In the thick syrupy juice of the date this increased mobility of the invertase must greatly accelerate its action. This accounts for the more rapid disappearance of cane sugar after ripening.

The difference in behavior of the two classes of dates during ripening suggested that the presence or absence of invertase must be the determining factor, and accordingly, the inverting power of a Deglet Noor glycerin extract was tested as follows: 100^{cc} of date extract was

added to 2000^{cc} of 5 per cent. sugar solution, which was divided into portions of 200^{cc} each; one series, containing boiled and unboiled samples, was placed in an incubator at 49° C; the other was left at room temperature. After twenty-four hours no change could be noted in either series. It appeared that Deglet Noor contained no invertase.

A series of comparative extracts of Deglet Noor and three invert sugar dates was then prepared, using five parts of glycerin and seven parts of date, and pressing after digesting together for twenty-four hours or longer. In the tests the same quantities of 5 per cent. sugar solution and of date extract were used in each case. The preservative used throughout was thymol. The figures show the reading on the saccharimeter when portions of the solution were weighed off and treated in the usual manner. It will be noted that the inversion in the case of the three invert sugar dates follows, in a general way, the mass law as found by O'SULLIVAN and THOMPSON[35] for yeast invertase. In another series all the invert sugar date extracts were found to work better at 35° C, but the optimum was not determined.

INVERTING POWER OF DATE EXTRACTS

Date	Hour	Deglet Noor	Rhars	Birket el Haggi	Row 12, no. 7
Nov. 6	2 P. M.	5.14	4.51	4.47	4.49
" 6	5 P. M.	5.05	4.32	4.33	4.26
" 7	9 A. M.	5.17	3.36	2.92	3.05
" 7	4 P. M.	5.19	3.01	2.61	2.72
" 8	9 A. M.	5.18	0.81	1.13	1.04
" 9	9 A. M.	5.16	−1.69	−0.65	−1.41
" 10	9 A. M.	5.15	−1.77	−1.99	−1.58
" 12	9 A. M.	5.15	−1.92	−1.79	−1.76

The question then arose as to whether the Deglet Noor contained no invertase or whether an inhibiting substance was present. The first experiment had already shown that the failure to invert was not due to low temperature. Accordingly a series of tests with equal amounts of invert sugar date extract were arranged and increasing amounts of Deglet Noor extract added until 100^{cc} of the latter were present to 25^{cc} of the former. In no case could a diminution of the inverting power of the invert sugar date extract be observed. To make this matter more certain, a concentrated aqueous extract of

[35] Invertase, a contribution to the history of an enzyme or unorganized ferment. Jour. Lond. Chem. Soc. **57**:834. 1890.

Deglet Noor was prepared and found to contain, per liter, 90.32^{gm} cane sugar, 18.81^{gm} fructose, and 17.78^{gm} glucose. A similar artificial mixture was made and both treated with equal amounts of Rhars extract. The natural Deglet Noor extract was inverted slightly faster than the artificial one. This proved that no antiferment was present.

While glycerin extracts of Deglet Noor and M'Kentichi Degla fail to invert solutions of cane sugar, the presence of considerable quantities of invert sugar in these dates points with certainty to invertase. It is untenable, moreover, to consider that these dates differ from the invert varieties merely in quantity of invertase without other qualifications, for a very small amount of invertase will invert a very great amount of cane sugar. O'SULLIVAN found that one part of crude invertase inverted 100,000 parts of cane sugar and still retained its inverting powers. It must be remembered also that a significant amount of invert sugar is formed in a very short time about the period of softening, and that this amount is greater under changed conditions, especially the higher temperature and moisture required for artificial ripening. The inverting action, however, is limited, for cane sugar determinations in samples one year old showed for Deglet Noor 42.14 per cent., M'Kentichi Degla 59.05 per cent., Saffraia 2.96 per cent. The same sample of Saffraia one year before contained nearly 4 per cent. cane sugar. This failure to invert is not due to the invertase becoming inactive, for a Rhars extract made from dates stored one year was fully as active as fresh date extract. A portion of the pulverized Saffraia used above, tested for inverting powers, proved to be one of the strongest preparations examined. These phenomena seem to be due to the localization of the invertase, which means suppression of invertase-secreting tissue. The only thing that could have prevented the inversion of the residual cane sugar in the Saffraia must have been inability to come into molecular contact with the enzyme. The tissues of all dates exhibit inverting powers, although the cane sugar varieties show it but feebly. The failure of their glycerin extracts to invert is probably due to the very small amount of invertase remaining in the same condition as it exists in the green invert sugar date.

Two ways suggest themselves for studying the distribution of the

invertase: testing various portions of the date for inverting power, and comparative analyses of the various parts. Suitable materials for carrying on these lines of work were exhausted this year before a fair start could be made. It is our expectation to continue this phase of the work. Preliminary tests by the first method—dividing the date transversely into blossom third, middle third, and stem third; and concentrically into three parts, the outer shell down to the tannin layer, the tannin layer, and the inner portion—failed to give trustworthy results.

The physiological function of the tannin is little understood. Whatever else it may do, it efficiently protects the fruit from animal ravages and permits it to mature its seed, as has been demonstrated in the Tempe orchard this year.[36] The loss of astringency on ripening was formerly believed to mark the conversion of tannin into sugar, but it was found that in the persimmon[37] the tannin only becomes insoluble. This has been found by THORNBER[38] and the writer to be true of the date also. SLADE considered the tannin present as glucoside which was in some way split up, the tannin being oxydized by an oxydase; and in fact some experiments in which the loss of astringency and softening appeared to have been hastened by the use of manganese salts gave some ground for this opinion. This was further supported by the observations of TICHOMIROW.[39] Even if true, the tannin or tannin-glucoside is so small in amount that it could not appreciably interfere in the carbohydrate relation. Many other quantitatively minor changes undoubtedly take place at the time of softening, among others the change in the behavior of the invertase toward solvents, which I hope to discuss at length in some future paper.

There remains at least one other way in which cane sugar dates differ chemically from invert sugar dates. E. E. FREE, who assisted in these experiments, noticed and called my attention to the fact that sugar solutions to which cane sugar date extracts had been added developed a pink tint. This was more pronounced and developed

[36] Annual Report, Ariz. Agric. Exp. Sta. **17**:164.

[37] BIGELOW, GORE, and HOWARD, *loc. cit.*

[38] *Loc. cit.*

[39] Compt. Rend. **39**:305. 1904; through notes of H. B. SLADE.

quicker in boiled solutions than in unboiled, and it was therefore not an enzyme reaction. We found oxygen essential to the color development, because solutions kept in an atmosphere of hydrogen over alkaline pyrogallol never turned pink, even in the bright sunlight, where they were heated to 50 or 55° C. Either in the dark or in the sunlight the color developed readily if free access of oxygen was allowed. This change was never noticed when using invert sugar date extracts. Whether or not it has any connection with the invertase is unknown.

Aside from the chemical classification into cane and invert sugar dates, there is also a physical one into dry and soft dates. We find both cane and invert sugar dates in the dry class as well as in the soft. The Deglet Noor is a typical cane sugar date, yet decidedly a soft date. The M'Kentichi Degla is also a cane sugar date, but of the hard class. The Saffraia, on the other hand, is as typical a hard date as the M'Kentichi Degla, but for all that practically an invert sugar date. The Halloua is a hard but only partial cane sugar date, somewhat similar in sugar content to the artificially ripened Deglet Noor, i. e., about 20 to 25 per cent. of cane sugar. In ripening, the hard dates do not soften or change color; they remain yellow. They shrivel somewhat, but this cannot be used as an index of ripeness, because the shriveling begins before the astringency disappears.

The origin of the cane and invert sugar dates is obscure, and the varieties have existed several hundred years. Nothing is known as to whether they originated from seedlings or were sports. They are now propagated only from suckers. It will prove interesting to study the seedlings to determine whether a cane sugar date can be obtained from a cane sugar date seed. This is an inviting field of investigation, but, due to the slow development of the plant, would require several generations of investigators.

AGRICULTURAL EXPERIMENT STATION
TUSCON, ARIZONA

NEW OR NOTEWORTHY NORTH AMERICAN CONVOLVULACEAE

HOMER D. HOUSE

(WITH FOUR FIGURES)

The following notes and descriptions of some American species of the Convolvulaceae are based mainly upon material in the herbarium of the United States National Museum, and my thanks are due to Dr. J. N. ROSE and Mr. JOSEPH H. PAINTER of that institution for the privilege of examining and studying the specimens.

Ipomoea petrophila, sp. nov.—§ ORTHIPOMOEA; *Suffruticosae.*—Erect or the branches ascending from a perennial root; stems pale and finely tomentulose, especially above, 30–60^{cm} high: leaf-blades lanceolate, sometimes broadly so, 4–10^{mm} long, obtuse at apex, obtuse or tapering and 3-nerved at base, greenish and finely sericeous-pubescent above, more densely so beneath: sepals unequal, oblong or elliptical-oblong, obtuse, the outer ones 6–8^{mm} long, finely pubescent, the inner ones glabrous, 8–11^{mm} long: corolla white with a cream-colored throat, 6–8^{cm} long, glabrous: peduncles 1–5^{cm} long, 1–3-flowered; pedicels somewhat thickened but not fleshy, 1–2^{cm} long: capsules conical-ovoid, 14–16^{mm} high, 2-celled, thick-walled, topped by the persistent base of the style which falls away at maturity, 4-valved, 4-seeded; seeds brownish, 3-angled, about 7^{mm} long, the two dorsal angles with a dense coma of white hairs nearly the length of the seed.

MEXICO: State of Chihuahua, rocky hills near Chihuahua, *Pringle* 340, Aug.–Sept. 1885; type, sheet no. 40372 in U. S. Nat. Herb., Sta. Eulalia Plains, Chihuahua, *Wilkinson,* July and Oct. 1885.

The type sheet bears the determination "*I. longifolia* Benth.," to which the species is evidently related.

Ipomoea ciervensis Painter, sp. nov.—§ORTHIPOMOEA; *Suffruticosae.*—Perennial; stems erect, bushy, woody below, 30–60^{cm} tall, densely white tomentulose and pubescent throughout except on the corolla: leaves crowded; leaf-blades sessile or the petioles 1–8^{mm} long, elliptical-lanceolate to obovate-lanceolate, 3–5-nerved at the

obtuse base, apex acute or the larger leaves obtuse and somewhat 3-lobed at apex, 4–6^{cm} long, 2–4^{cm} broad, more densely white tomentulose and pubescent beneath than above: peduncles about 1^{cm} long, the two bracts approximate to the calyx, linear-spatulate or sometimes subfoliaceous, 14–16^{mm} long or rarely longer: sepals equal, ovate-lanceolate, attenuate, about 15^{mm} long, glabrous within: corolla white, about 6^{cm} long, pubescent without in bud, strigulose without on the margins of the plicae when expanded: stamens less than half the length of the corolla; filaments glandular-pubescent and expanded below: stigma capitately 2-lobed; ovary 2-celled.

MEXICO: State of Queretaro, Hacienda Ciervo, between San Juan del Rio and Cadereyta, *Rose* and *Painter* 9660, Aug. 20, 1905; type, sheet no. 453150 in U. S. Nat. Herb. Del Ciervo et Cerro de la Messa, *Dr. Altamirano* 1557, Aug. 20, 1905.

The mature capsules and seeds of this remarkable species have not been seen, but it is closely related to a group of species of similar habit abundantly represented in the Brazilian flora, with thick-walled ovoid capsules and seeds with a coma of hairs on the dorsal angles. In North America its nearest but by no means close allies are *I. petrophila* House and *I. longifolia* Benth., natives of regions much further north.

Ipomoea glabriuscula, sp. nov.—§ ORTHIPOMOEA; *Arborescentes.*—Erect, woody and probably tree-like, glabrous or nearly so: leaf-blades ovate, short-acuminate, shallow cordate, 5–8^{cm} long, 4–7^{cm} broad below the middle, glabrate above, minutely and sparingly pubescent beneath; petioles 3–4^{cm} long, slender: peduncles exceeding the subtending petioles, often the blades, 4–12^{cm} long, branching, 4–many-flowered; pedicels about 1^{cm} long, not thickened: sepals unequal, orbicular, glabrous, the outer ones 4.5–5^{mm} long, the inner 6–7^{mm} long: corolla white, slender funnelform, about 6^{cm} long, glabrous or with some slight pubescence on the plicae without.

GUATEMALA: *Enrique Th. Heyde,* 1892; type, sheet no. 256072 in the U. S. Nat. Herb.

Related to *I. fistulosa,* from which it differs by its glabrous or nearly glabrous calyx and corolla, its broader and relatively shorter leaf-blades, and the young parts glabrous.

Ipomoea nicaraguensis (Donnell Smith).—*Ipomoea fistulosa* var. *nicaraguensis* Donnell Smith, BOT. GAZETTE **19**:256. 1894.—§ ORTHIPOMOEA; *Arborescentes.*—A small tree with velvety canescent twigs:

leaf-blades broadly ovate or reniform-ovate, shallow cordate, acute, mucronate, 7–12^{cm} long and nearly as broad, green and minutely but densely pubescent above, velvety-canescent beneath; petioles 3–4^{cm} long: peduncles several-flowered; pedicels 4–8^{mm} long: sepals broadly ovate, rounded, minutely tomentose without, about 7^{mm} long, equal: corolla white or pinkish, 6–7^{cm} long, the tube rather slender, tomentose without on the plicae of the limb.

Type locality: Rio de las Lajas, Dept. Rivas, Nicaragua, alt. 120^{m}. *W. C. Shannon* 5046, April 1893. Herbarium sheet no. 246468 of the duplicate in the U. S. National Museum.

Ipomoea cuernavacensis, sp. nov.—§ORTHIPOMOEA; *Arborescentes.*—Closely related to *I. arborescens* (Willd.) G. Don, and resembling it in habit and characters of all parts excepting the leaves; leaf-blades oblong, rounded at base, not cordate, long-acuminate, 10–15^{cm} long, 5–6.5^{cm} broad.

MEXICO: In fields near Cuernavaca, state of Morelos, *Rose* and *Painter* 6963, Sept. 10, 1903.

Ipomoea calva, sp. nov. (*fig. 1*).—§ ORTHIPOMOEA; *Arborescentes.*—An irregular tree, 6–7^{m} tall, glabrous or nearly so: bark of branches and twigs whitish: leaves clustered near the ends of the twigs; blades small, 2.3^{cm} long, ovate-lanceolate, attenuate to a blunt, mucronulate apex, the base obtuse or rounded, 8–12^{mm} broad below the middle, glabrous above, puberulent on the veins beneath; petioles shorter than the blades, 1–2^{cm} long: peduncles 1-flowered, the pedicel portion subsessile, about 2^{cm} long, slightly thickened upward: sepals coriaceous, minutely puberulent, subequal, broadly oblong, rounded, 8–10^{mm} long: corolla campanulate-funnelform, white, 4.5–5^{cm} long; limb spreading, about 4^{cm} broad, with five short rounded lobes; tube about 1^{cm} in diameter.

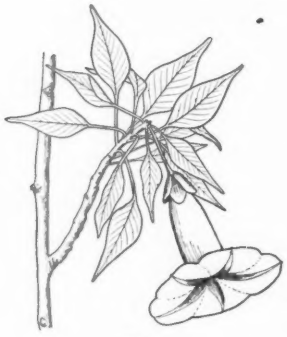


FIG. 1

MEXICO: State of Guerrero, La Junta, *E. W. Nelson* 6992, April 5, 1903; type in U. S. Nat. Herb.

Related to *I. Wolcottiana* Rose, from which it differs by its smaller corolla and smaller leaves of different shape.

Ipomoea Lozani Painter, sp. nov. (*fig. 2*).—§ STROPHIPOMOEA; *Integrifoliae*.—Perennial, at least below, twining, 1–2^{m} long or more: stems herbaceous above, glabrous: leaf-blades narrowly ovate, deeply cordate-sagittate, abruptly narrowed, attenuate and mucronate, 5–8^{cm} long including the basal auricles which are rounded, converging, and often overlapping; petioles as long as the midvein of the blade, or slightly longer: peduncles 1-flowered, shorter than the subtending petioles, finely pubescent especially near the base; pedicel portion puberulent, thickened and fleshy, 3–4^{cm} long: sepals equal, coriaceous, puberulent and slightly tentacular, oblong-lanceolate, 12–14^{mm} long, acute: corolla campanulate-funnelform, blue or purple, 6–7^{cm} long; the somewhat 5-lobed limb as broad; tube whitish below.

FIG. 2

MEXICO: State of Queretaro, stony hillside near San Juan del Rio, *Rose* and *Painter* 9542, Aug. 18, 1905; type, sheet no. 453033 in U. S. Nat. Herb.

Related to *I. tentaculifera* Greenm. but with deeper cordate leaf-blades, shorter peduncles and pedicels, and less tentacular sepals.

Ipomoea mestecensis, nom. nov.—*Calonyction dubium* Mart. & Gal. in Bull. Acad. Brux. XII. **2**:268. 1845. *Ipomoea dubia* Hemsley, Biol. Cent.-Am. Bot. **2**:368. 1882; not *I. dubia* R. & S. Syst. **4**:216. 1819.

Type locality: In woods, Mesteca and Yavesta, Oaxaca, Mexico.

Distribution: Woods, southern Mexico in the state of Oaxaca.

Specimens examined: OAXACA; Sierra de San Felipe, *Chas. L. Smith* 910, 1894, alt. 7000–8000^{ft}; foothills near Oaxaca, *Pringle* 4693, 1894, alt. 6000–7000^{ft}.

Ipomoea silvicola, sp. nov. (*fig. 3*).—§ STROPHIPOMOEA.—Twining, probably several meters high, slender: stems pubescent above: leaf-blades orbicular-ovate, cordate, acuminate, entire or 3-lobed, the

lateral lobes rather high on the blade, 5–12^{cm} long, appressed pubescent above, more densely so beneath, the young leaves sericeous pubescent; petioles pubescent, mostly shorter than the blades: peduncles less pubescent than the subtending petioles and exceeding them: sepals unequal, lanceolate, acuminate, 18–28^{mm} long, appressed pubescent and densely tentacular below, nearly glabrous toward the apex: corolla campanulate-funnelform, 6–7^{cm} long, blue, glabrous; the limb as broad and with five rounded lobes.

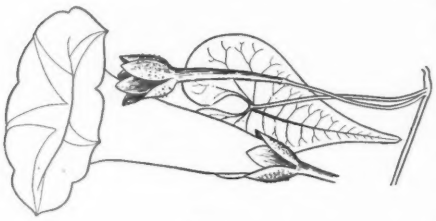


FIG. 3

GUATEMALA: Rio de Las Canas, Dept. Santa Rosa, alt. 1000^{m}, *Heyde* and *Lux.*, Sept. 1892 (*John Donnell Smith* distribution number 4022); type, sheet no. 354958 in U. S. Nat. Herb.

The type sheet bears the determination "*I. macrantha* Peter," to which this specimen is not closely related. *I. macrantha* Peter is a homonym several times over, and according to HALLIER is *Calonyction campanulatum* Hallier f.

Ipomoea collina, sp. nov. (*fig. 4*).—§ STROPHIPOMOEA.—Twining, slender: stems several meters long, probably perennial below; stems, petioles, and peduncles minutely pubescent or puberulent: leaf-blades ovate, cordate, 3–7^{cm} long, deeply 3–5-lobed, the middle lobe contracted below into a slender base, the lateral lobes narrower, basal lobes often bifid or coarsely toothed; petioles as long as the blades or shorter, slender and almost filiform: peduncles 1–5-flowered, stout,

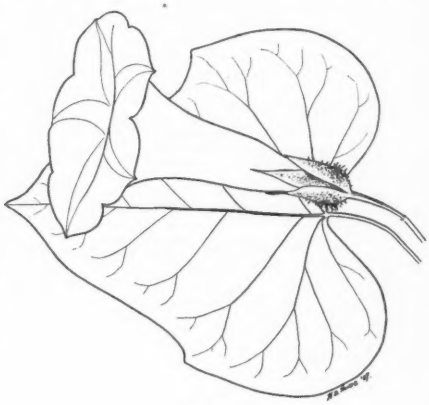


FIG. 4

exceeding the subtending leaves, 13–25^{cm} long; bracts small or lacking; pedicels 1–3^{cm} long, somewhat thickened: sepals unequal, 8–14^{mm} long, lanceolate, subcoriaceous, the outer shorter and with some slight scattered pubescence, the inner ones longest, glabrous, cuspidate-acute and scarious margined: corolla bright blue with a white tube, 5–7^{cm} long; limb as broad, subentire; tube broad and expanding campanulate from above the calyx: stamens unequal; anthers sagittate at base: stigma with two nearly distinct globose lobes; capsules ovoid, 2-celled, 4-seeded.

MEXICO: State of Coahuila, San Lorenzo Cañon, six miles southeast of Saltillo, *Palmer* 396, Sept. 21–23, 1904; type, sheets nos. 471266 and 471265 in U. S. Nat. Herb.

Related to *I. laeta* A. Gray, from which it differs by its much smaller corolla, longer peduncles, and more glabrous habit.

Ipomoea Plumieriana, nom. nov.—*Convolvulus coccineus heptaphyllos, radice crassissima* Plum. Cat. 1. 1703; Plum. Amer. 79. *pl. 90. f. 1.* 1755 (excl. syn. Sloan, Browne and Pluk.). *Convolvulus macrorhizos* L. Syst. ed. X. 923. 1759; Sp. Pl. ed. 2, 223. 1762; Ders. in Lam. Encyl. **3**:567. 1789. *Ipomoea marcorhizos* R. & S. Syst. **4**:211. 1819; Choisy, in DC. Prodr. **9**:388. 1845; Urban, Symb. Ant. **3**:352. 1902; not *I. marcorhiza* Michx. Fl. Bor. Am. **1**:141. 1803. *Batatas macrorhizos* G. Don, Gen. Syst. **4**:261. 1838. *Ipomoea heptaphylla* Griseb. in Mem. Am. Acad. **8**:(Pl. Wright.) 527. 1863; not *I. heptaphylla* Voigt. Hort. Suburb. Calc. 360. 1845, and others. —Glabrous, twining, stout, 10^{m} high or more: leaf-blade digitately 7(rarely 5, 6, or 8)-divided; segments stalked, elliptical-oblong to lanceolate, broadest above the middle, tapering to an acuminate base, apex abruptly acuminate or nearly obtuse, membranaceous or chartaceous, 5–10^{cm} long, entire; petioles usually a little shorter than the middle segment: peduncles shorter than the subtending petioles, 1–6^{cm} long, 1–1.5^{mm} thick, 2–10-flowered; primary pedicels 1–1.5^{cm} long, somewhat thickened in fruit: sepals unequal, the inner a little longer than the outer ones, suborbicular, 9–10^{mm} long: corolla scarlet, purple or purplish-red, 5^{cm} long or less, dilated-campanulate above the calyx; tube about 20^{mm} thick: stamens 15–25^{mm} long; anthers usually protruding: capsules twice as long as calyx, thickest above the middle, 2-celled, 4-seeded; seeds blackish,

covered on the dorsal angles with a long coma of cinnamon-brown hairs.

Distribution: West Indies, throughout the Greater Antilles, Cuba, Jamaica, St. Domingo, etc.

Illustrations: Plum. Amer. *pl. 90. f. 1.*

Specimens examined: JAMAICA: Gordontown Road, *Harris*, Jan. 7, 1902; Barrack Hill, *W. Cradwick*, July 1890. CUBA: *Wright* 1371, 1860–64.

Ipomoea rubella, nom. nov.—*Ipomoea pulchella* W. Hook. Bot. Mag. **73**: *pl. 4305.* 1847; not *I. pulchella* Roth. Nov. Pl. Sp. 115. 1821, and others. *I. macrorhiza* Griseb. Fl. Br. W. Ind. 471. 1864; not *I. macrorhizos* R. & S. Syst. **4**:211. 1819, nor *I. macrorhiza* Michx. Fl. Bor. Am. **1**:141. 1803. *I. Grisebachii* Urban, Symb. Ant. **3**:353. 1903; not *I. Grisebachiana* Meissn., Peter in Engler & Prantl, Natürl. Pflanzenfam. IV. **3a**:30. 1891.

Type locality and distribution: Jamaica.

Illustrations: Bot. Mag. *pl. 4305.*

Operculina ornithopoda (Robinson), comb. nov.—*Ipomoea ornithopoda* Robinson, Proc. Am. Acad. **27**:183. 1892; Greenman, *l. c.* **39**:84. 1903. *Operculina angustiloba* House, Bull. Torr. Bot. Club **33**:501. 1906.

MEXICO: San Luis Potosi, hills, Canoas, *Pringle* no. 3553, July 1890 (type in herb. Gray); near San Dieguito, *Palmer* no. 112, June 12–16, 1904 (type of *O. angustiloba*, in herb U. S. Nat. Museum).

When the original descriptions of *Operculina Roseana* and *O. angustiloba* were drawn up, the identity of them with *Ipomoea ornithopoda* Rob. was not suspected, for the reason that the description of the latter species does not mention the character of the operculate capsule. The species has two extremes of leaf-form in Mexico: one with very narrow lobes to the leaf-blade, typical *O. ornithopoda*; and another with relatively broader and shorter lobes, *O. Roseana* House, regarded by GREENMAN as essentially the same species. It will be noted, however, that the narrow-lobed species (*O. ornithopoda*), so far as known, is confined to San Luis Potosi; while *O. Roseana* ranges from Sonora to Chiapas and Morelos, quite a different geographical and climatic region. Until specimens of intermediate distribution and characters are brought to light, the writer feels justified in maintaining both species.

CLEMSON COLLEGE, S. C.

BRIEFER ARTICLES

HETEROTHALLISM IN BREAD MOLD, *RHIZOPUS NIGRICANS*

In recent publications the writer has shown that, according to their method of sexual reproduction, the Mucorineae may be divided into two groups—homothallic and heterothallic. In a homothallic species, zygospores are formed from branches of the same mycelium and can be obtained from the sowing of a single spore. In heterothallic species, which probably constitute the large majority of the Mucorineae, zygospores are formed from branches which necessarily come from two different mycelia belonging to sexually opposite races or strains. By sowing a single spore, therefore, one cannot obtain zygospores of a member of the heterothallic group unless the culture becomes contaminated with spores of the opposite strain.

Within the last few months, two communications have appeared which claim that the production of the zygospores of Rhizopus is not at all dependent upon the presence of two sexual races; in other words, that on the proper nutrient the zygospores can be obtained from the sowing of a single spore. This laboratory weed, the common bread mold, is the best known species among the mucors and has been used as a type of the heterothallic group.

A propos of the article by HAMAKER (Science N. S. **23**:710. 1906), the writer has recently summarized the results of a series of investigations on the sexual condition in this species covering a period of over six years (Science N. S. **24**:118–122. 1906). Since this was written, the preliminary communication of HAMAKER has been reviewed in the BOTANICAL GAZETTE (**42**:77. 1906) where the detailed formula is repeated for making the corn muffin bread claimed to be a sure medium for the production of the zygospores of this species. It is not the purpose of the writer to repeat what has been said already in regard to the inadequacy of this nutrient theory of zygospore formation. It seems desirable, however, to consider somewhat in detail the paper of NAMYSLOWSKI (*Rhizopus nigricans* et les conditions de la formation de ses zygospores: Bull. Acad. Sci. Cracovie 676–692. *pl. 21.* 1906), since this investigator explicitly casts doubt upon the occurrence of heterothallism in any of the Mucorineae and would give the appearance of supporting his conclusions by cultural experiments with Rhizopus.

It may be said at the start that, as every laboratory mycologist knows, Rhizopus shares with Penicillium the distinction of being the worst fungus weed in laboratory cultures, and is practically certain to come as a contamination of substrata rich in carbohydrates unless they be sterilized and *kept* under sterile conditions. In the Harvard laboratory, as in most other botanical institutions, Rhizopus is obtained for class use by spontaneous infection of bread. Moreover, the sporangium wall is brittle and when ruptured the spores are discharged into the air. It is somewhat difficult, therefore, to obtain a pure transfer from a single sporangium without contamination with spores of other sporangia near by, and, before the discovery of heterothallism in this form, the writer more than once obtained zygospores from transfers which at the time were thought to have come from single sporangia.

NAMYSLOWSKI's conclusions are based for the most part on two series of cultures. In the first, 19 bread cultures were made from spores from one single sporangium, and zygospores were produced in every case. In the second series, 46 single spores were isolated by the separation method and used in the inoculation of cultures chiefly of bread. Of these 6 were destroyed by bacteria, 13 produced only a feeble growth of mycelium (probably also infected by bacteria), 13 only sporangia, and 14 zygospores. The failure to obtain zygospores in so large a number of the sowings is ascribed to improper moisture content of the air in the cultures and to other unfavorable conditions which are not further investigated.

Two explanations are possible for these results: (1) that NAMYSLOWSKI was in fact dealing with a homothallic form of Rhizopus and zygospores were the result of single spore sowings; (2) that infection from the air brought the (+) and (−) strains into contact and caused the production of zygospores. Mr. H. A. EDSON, of the Vermont Experiment Station, has recently sent the writer zygospores of Rhizopus which he writes were secured synthetically by opposing two strains, one obtained from Vermont, the other from Virginia. A dozen strains were tested by him from as many different sources, but failed to produce zygospores alone in pure cultures. The writer himself has tested 60 different strains from localities in such widely separated parts of the world as North and South America, England, Germany, France, Honolulu, and the Philippine Islands, and has found none which alone in pure cultures will produce zygospores. A homothallic form of the ordinary species, therefore, would seem *a priori* rather improbable, and to be proven only by careful cultures strictly under sterile conditions.

NAMYSLOWSKI says nothing about sterilizing his culture media, and the

fact that out of 46 cultures on bread, 6 (over 13 per cent.) were destroyed by bacteria and 13 more were probably also infected by bacteria, since they produced only a scanty mycelium devoid of fructifications, shows that NAMYSLOWSKI's cultures were far from pure, and renders it probable that, in the 14 instances in which zygospores were obtained out of the 46 cultures, the (+) and (−) strains had become present through infection; while in the 13 cultures in which only sporangia were obtained, whatever infection occurred was of the same strain as the spores used in the inoculation. The 19 cultures on bread from the same sporangium would give zygospores if the inoculating material became infected by spores of the opposite race before sowing, even though subsequent infection did not occur.

That zygospores may be obtained by accidental infection of a favorable substratum with both (+) and (−) spores has been repeatedly demonstrated by the writer's own experience in the Harvard laboratory. Professor CAMPBELL, moreover, has written that for ten years he has gotten zygospores by spontaneous infection of suitable substrata, and an investigation showed that in zygosporic material sent from his laboratory only the two (+) and (−) strains were present which alone were incapable of zygospore formation.

Since the above was written, Dr. NAMYSLOWSKI has kindly sent the writer zygosporic material of the *Rhizopus nigricans* which he used in his experiments. Inoculations were at once made into sterilized nutrient and a large number of the young zygospores resulting were isolated and laid on cleared nutrient agar in Petri dishes. Paired cultures X & XX and Y & YY were obtained by making mycelial transfers from the outgrowths from the suspensors of two zygospores both of whose suspensors had germinated. On the assumption that the species is heterothallic, each pair should contain the two opposite strains, and each strain when grown alone should be incapable of zygospore formation. In addition, cultures Z & ZZ were obtained from suspensors that could not be traced with certainty to the same zygospore, and cultures A–D were obtained from the germination of single isolated sporangiospores. By opposing inoculations from these cultures against one another and against standard (+) and (−) test strains, it was seen that X and Y are (−) and XX, YY, Z, ZZ, and A–D are (+). The contrasts numbered over 40 and were made for the most part on sterilized flour paste in stender dishes, but were controlled by cultures on nutrient agar in test tubes. None of the strains produced zygospores on substrata favorable to zygospore formation when sown alone in pure cultures, nor when sown together with the same strain from a different source. They have always formed them, however, whenever the opposite strains are grown

together under proper nutrient conditions. The form is therefore heterothallic.

Whether or not it may ever be found that a homothallic race may occur in a species normally heterothallic (perhaps not an impossible condition in view of the writer's having obtained a homothallic mycelium of the heterothallic Phycomyces), the evidence at hand leads one to the conclusion that the large majority of the Mucorineae are heterothallic.—A. F. BLAKESLEE, *Cryptogamic Laboratory, Harvard University.*

TWO EMBRYO-SAC MOTHER CELLS IN *LILIUM LONGIFLORUM*

(WITH ONE FIGURE)

The presence of more than one archesporial cell in the megasporangium of the Spermatophyta has frequently been reported for gymnosperms and dicotyledons, but the records of their occurrence in monocotyledons are very few. In 1882 GUIGNARD[1] figured two small hypodermal cells in *Ornithogalum pyrenaicum*, which he interprets as archesporial. As these cells are but little larger than the other cells of the nucellus, and the character of the protoplasmic content of the adjacent cells is not shown, the evidence here is not altogether conclusive. COULTER and CHAMBERLAIN[2] state that they have observed two preparations of *Lilium philadelphicum* showing respectively three and five archesporial cells, but they neither described nor figured them. BERNARD[3] observed and figured two four-celled embryo sacs

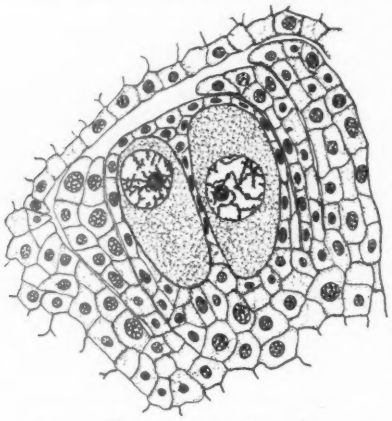


FIG. 1.—Vertical section through a young ovule of *Lilium longiflorum*, showing two embryo-sac mother cells.

[1] GUIGNARD, L., Recherches sur le sac embryonnaire des Phanérogames Angiospermes. Ann. Sci. Nat. Bot. VI. **13**:136–199. *pls. 3–7.* 1882.

[2] COULTER and CHAMBERLAIN, Morphology of Angiosperms. New York. 1903.

[3] BERNARD, C. H., Recherches sur les sphères attractives chez *Lilium candidum*, etc. Jour. Botanique **14**:178. *pls. 4–5.* 1900.

lying side by side in *Lilium candidum*. They are not separated by a layer of nucellar tissue, and the two are in intimate contact along their inner faces. Because of their position, BERNARD says it is impossible to determine whether they are derived from two archesporial cells or from one that has divided longitudinally. So far as I am aware, these are the only recorded instances of a multicellular archesporium in the monocotyledons.

In examining some slides of *Lilium longiflorum*, recently prepared by Miss ALLEN for general class use, I observed two megaspore mother cells in a single megasporangium. It is impossible in this instance that they should have arisen from the same primordial cell, since they are separated by a layer of somatic cells. As the accompanying figure shows, both are perfectly normal as to position, form, and protoplasmic content; the surrounding portions of the young ovule also present the usual appearances at the time just before the heterotypic division. There is every reason to expect that both of these archesporial cells would have given rise to normal female gametophytes.—MARGARET C. FERGUSON, *Wellesley College*.

CURRENT LITERATURE

BOOK REVIEWS

Recent textbooks

IN THE PREFACE of his *Principles of botany*[1] CHODAT announces that he intends to present a résumé, as concise as possible, of the general principles of botany, which presupposes of its readers such scientific preparation as is given in the secondary schools of France and Switzerland, i. e., the rudiments of natural and physical sciences. While attempting to state the facts in the precise language of physics and chemistry, he wishes readers to recognize that the phenomena are not reducible to the simple (*sic*) terms of these sciences. Not content with presenting only facts and definite theories, he calls attention to the unsolved problems as a stimulus to study. CHODAT disclaims the intention to write a treatise or a dictionary of botany, and limits his choice to those principles about which others may be conveniently and logically grouped. Keeping in mind the author's intention, we inquire how the book conforms to it.

In the first place, it is not so extensive as the number of pages would indicate. It is liberally and well illustrated, many of the figures being original and all on a rather large scale. Then the text is very open, much broken by paragraphing, a single sentence, sometimes one of only three or four words, commonly constituting a paragraph. That necessitates much more brevity than would be expected in 744 pages.

The book opens with the section on general physiology, in which are discussed the constitution of living matter and the acquisition and transformations of energy. In general this section covers the physics and chemistry of plants, arranged in somewhat novel fashion. Part of the chapter, as the discussion of the ionic theory, is thoroughly modern, but so condensed as to be far beyond the grasp of one who does not already know a good deal of physical chemistry; part, on the contrary, such as the distinctions in kinds of radiant energy, conforms to the current, though long outgrown, phraseology.

After a section on the cell and the tissues, including chapters on the cell, organogeny, and anatomy, the third section appears as special physiology. Here the chapters treat of "functions of elaboration" (including in this term, curiously enough, transpiration and the circulation [*sic*] of water and foods, but not photosynthesis; growth in the abstract, but not growth directed or controlled by external agents), "functions of relation," and "reproduction." The chapter on functions of relation discusses the responses to stimuli, formative and directive.

[1] CHODAT, R., Principes de botanique. 8vo. pp. viii+744. *figs. 829.* Genève: Georg et Cie. 1907.

In general the treatment of the physiological topics seems to us to lack balance. For example: twenty-four pages are devoted to climbing and twining plants, about as much as is given to tropisms in general and to the special phenomena of geotropism and phototropism, while all the others have a scant two pages; transpiration is given nine pages, but growth is dismissed in six; the enzymes are treated in sixteen pages, while photosynthesis with all its mechanism, energetics, and chemistry has scarcely eighteen, and proteid synthesis is allowed less than four. Further, the logical arrangement does not commend itself to us. Is there any sound reason for the curious distribution of topics already noted, or for treating the responses of "carnivorous plants" independently, and for combining with them the consideration of mycorhizal plants? If there is, the author has not made it evident in the text.

The section on reproduction (167 pp.) brings together in unusual form the usual data suggested by the title, each topic including illustrations from the whole plant kingdom. The presentation may be indicated by the principal topics, which are as follows: multiplication by division; multiplication by budding; multiplication by spores and zoospores; origin of spores in the Archesporeae and sporophyte of bryophytes; amphimixis, gametes, and gametangia; sporogenesis in the pteridophytes and spermaphytes; origin and development of megaspores; fecundation in spermaphytes; chromatic reduction; sexuality; secondary sexual characters; flowers of angiosperms; floral polymorphism; parthenogenesis; effects of fecundation; seeds; fruits; dissemination; germination. Some of the terminology used is revolutionary. For instance, in groups above thallophytes the mother cells are "tetrasporangia," the structure bearing sporangia is an "archidium" (the nucellus being a "megarchidium"), etc.

The last section deals with phylogeny, one of the chapters discussing variation and heredity, the other presenting the various theories of the origin of species.

The book seems not to offer the logical and balanced presentation that is essential to elementary students and therefore not to be well adapted to those for whom it is designed. At the same time, in its general facts and theories, as well as in the clear recognition of our ignorance in many fields, it is reliable, and its clear style makes it attractive.—J. M. C. and C. R. B.

LOTSY[2] has undertaken a gigantic task in preparing and publishing his lectures on the phylogeny of plants for the use of students of taxonomy. The first volume, devoted to the algae and fungi, makes a work of over 800 pages, illustrated by half-tones of 430 charts, each containing one to thirty figures; and he plans two other volumes covering in like manner the "archegoniates" and the spermaphytes. When one remembers that he has in hand the completion of his voluminous treatment of the theories of descent (*Vorlesungen über Deszendenztheorien*) and the editorial oversight of the *Botanisches Centralblatt*, in itself no

[2] LOTSY, J. P., Vorträge über botanische Stammesgeschichte, gehalten an der Reichsuniversität zu Leiden. Ein Lehrbuch der Pflanzensystematik. Erster Band: Algen und Pilze. Imp. 8vo. pp. iv+828. *figs. 430.* Jena: Gustav Fischer. 1907. *M*20.

mean task, one is in doubt whether to wonder most at his capacity or his temerity.

This work consists of an orderly account of the structure and life-history of selected species of various groups, which illustrate best the progression or regression along developmental lines, so far as available literature presents it. Especially, LOTSY endeavors to distinguish the sporophyte and gametophyte generations, or as he calls them on the criterion of chromosomes the x and $2x$ generations. Developmental features of nutrition, cytology, and reproduction are treated in connection with forms that suggest the topic.

Avowedly, the work is a compilation of current literature, and it would be too much to expect that it contain no errors nor oversights. An inspection, with special reference to the work of Americans, reveals an unexpected and welcome completeness, so far at least as the major papers are concerned, and this is probably equally true of the European literature. The work is indeed a thesaurus of information, and its treasures are made thoroughly available by a very complete index. There is no doubt that the hope of the author will be amply fulfilled: "Should the book win new friends for taxonomy, or give young investigators a better insight into the live questions of classification, or even save one or another some labor and so give more time to new investigation, the author will be requited for his trouble."—C. R. B.

A SECOND EDITION of CAMPBELL'S *University textbook of botany*, "revised and corrected," has appeared.[3] There is no prefatory note to call attention to the revised portions of the book, and since the pagination of the two editions is identical, it is evident that only such revision was attempted as could be made upon the stereotyped pages. Just what these changes are could be discovered only by a laborious comparison of the two texts. The first edition, which reappears in this second edition, was reviewed in this journal (34:67. 1902). The call for a second edition indicates that there is a demand for a general textbook of botany of college grade.—J. M. C.

A SECOND and much enlarged edition of KRAEMER'S *Textbook of botany and pharmacology* has appeared.[4] The book represents what is demanded of students of pharmacy in the way of botanical information. The three parts of the volume bear the titles Botany (416 pp.), Pharmacognosy (381 pp.), and Reagents (8 pp.). The botanical section presents the principal groups of plants, from thallophytes to spermaphytes, in such an account as would be given in a short course in elementary morphology; the "outer morphology" of angiosperms; the "inner morphology" or histology of the higher plants, including the cell contents; a classification of angiosperms yielding drugs; the cultivation of medicinal plants. If the general anatomical and morphological features of plants as presented in the text are backed up by laboratory work, the student of pharmacy will obtain a

[3] CAMPBELL, DOUGLAS HOUGHTON, A University textbook of botany. Pp. xv+579. New York and London: The Macmillan Company. 1907. $4.00.

[4] KRAEMER, HENRY, A textbook of botany and pharmacognosy. pp. vi+840. Philadelphia and London: J. B. Lippincott Company. 1907. $5.00.

good introduction to the scientific aspects of botany before he reaches the professional details as to drugs. The illustrations are well selected and admirably executed.—J. M. C.

BERGEN and DAVIS have prepared a manual[5] to accompany their *Principles of botany*, reviewed in this journal (**43**:64. 1907). As a guide to teachers not familiar with material or its use the manual should prove of great service. As in every other manual, a selective use of the material is expected, and hence almost any elementary teacher with almost any length of course and any kind of material may find helpful suggestions.—J. M. C.

NOTES FOR STUDENTS

Phototropism.—Exactly opposite results to those of HABERLANDT[6] have been reached by KNIEP[7] working in PFEFFER's laboratory. By painting with paraffin oil the surface of leaves of a number of species cited by HABERLANDT in his *Lichtsinnesorgane* and covering this layer of oil with thin sheets of mica, or in the case of humpy leaves with thin paper, KNIEP eliminated the lens-action of the epidermal cells, to which HABERLANDT ascribes the perception of light. But whereas HABERLANDT in similar experiments, using water instead of oil for obviating the lens-action, found that the leaves do not respond to oblique light, KNIEP finds that they do, behaving just as the control plants without oil. KNIEP devised ingenious methods of shading the petiole completely, excluding even the light transmitted through the blade at the point of attachment of the petiole. He also adapted the method of conducting light through a glass rod, once proposed for microscope illumination, to the illumination of his experimental leaves.

The increasing number of squarely contradictory results in the field of irritable phenomena makes it evident that there is need of more cautious analysis of the possible factors and more extended and careful experimentation before reaching and publishing conclusions.—C. R. B.

Secondary thickening.—Last year URSPRUNG published a preliminary note in the *Berichte* of the German Botanical Society,[8] declaring that the pith in *Sambucus nigra* continued its growth in the second and third year, and that even the wood cells were capable of dividing and increasing the thickness of their walls as well as their diameter. Although it is a well-known fact that these cells are all dead, SCHELLENBERG[9] goes to the trouble of demolishing URSPRUNG's foolish allegations in all sobriety and with all the enginery of original research. As URSPRUNG gave measurements which might have misled, perhaps this ponderous refutation was necessary; but it has its humorous aspect.—C. R. B.

[5] BERGEN, JOSEPH Y., and DAVIS, BRADLEY M., Laboratory and field manual of botany. pp. viii +257. Boston: Ginn and Company. 1907.

[6] BOT. GAZETTE **42**:399. 1906.

[7] KNIEP, HANS, Ueber die Lichtperzeption der Laubblätter. Biol. Centralbl. **27**:97–106, 129–142. *figs.* 28. 1907.

[8] URSPRUNG, A., Ueber die Dauer des primären Dickenwachstums. Ber. Deutsch. Bot. Gessells. **24**:493. 1906. Cf. BOT. GAZETTE **43**:294. 1907.

[9] SCHELLENBERG, H. C., Ueber das primäre Dickenwachstum des Markes von *Sambucus nigra*. Ber. Deutsch. Bot. Gesells. **25**:8–16. 1907.

NEWS

FREDERIC E. CLEMENTS, University of Nebraska, has been elected professor of botany, in charge of the department, in the University of Minnesota, as successor to Professor CONWAY MACMILLAN.

DR. AND MRS. N. L. BRITTON, N. Y. Botanical Garden, and Dr. C. F. MILLSPAUGH, Field Museum of Natural History, have returned from a botanical survey of the outer islands of the Bahamian archipelago.

F. R. KJELLMAN, professor of botany in the University of Upsala, died April 22. On November 4, 1906, a memorial volume (*Botaniska Studier*) was issued by his students, commemorating his 60th birthday.

DR. A. F. BLAKESLEE, Harvard University, has been elected professor of botany in the Connecticut Agricultural College, at Storrs. He will begin his duties by acting as the director of the summer school of 1907.

RHODORA (9:29–55. 1907) has published the international rules for botanical nomenclature adopted by the Vienna Congress, and has appended a list of New England genera whose names are to be retained notwithstanding technical lack of priority.

THE NEW YORK ACADEMY OF SCIENCES observed the 200th anniversary of the birth of Linnaeus by a very full program of exhibits and addresses. The zoologists and botanists united in commemorating the occasion, and a bronze tablet was unveiled at the bridge over Bronx River in Pelham Parkway, a position appropriately between the Botanical Garden and the Zoological Park.

THE ANNUAL REPORT of the director of the Field Museum of Natural History (Chicago) shows that during 1906 there were added to the herbarium 11,403 sheets, and that the total number of sheets in the organized herbarium on November 25, 1906, was 110,712. The organization of this herbarium under Dr. CHARLES F. MILLSPAUGH is one of the most effective and complete in existence and its rapid growth indicates that it is to become one of the great herbaria.

THE HARPSWELL LABORATORY on the coast of Maine has its eighth session from June 17 to September 9, 1907. It is situated in South Harpswell near the extremity of a narrow peninsula nearly ten miles in length, extending out into Casco Bay. This bay has a very rich fauna and flora and is not excelled as a collecting-ground by any point between Eastport and North Carolina. The woods are mostly evergreens and are inhabited by a diversified plant and animal population. The director, to whom all communications should be sent, is Professor H. V. NEAL, Knox College, Galesburg, Illinois.

GENERAL INDEX

The most important classified entries will be found under Contributors, Personals, and Reviews. New names and names of new genera, species, and varieties are printed in **bold-face** type; synonyms in *italic*.

A

Abutilon Thompsoni, infectious chlorosis in, Baur on 287
Acids, assimilation of organic by algae, Tréboux on 147; hydrocyanic in plants, Guignard on 288
Achillea millefolium, Fawcett on 348
Acrochaetium, Collins on 71
Adenostegia, Rydberg on 348
African cycads, Pearson on 292
Agave, Berger on 146
Agialidaceae, Van Tieghem on 146
Agiella, Van Tieghem on 147
Alaskan mosses, Cardot and Thériot on 348
Albugo, Wilson on 348
Alcohol, effects on wheat 39
Alfalfa seed of Kansas, Roberts and Freeman on 356
Algae, of Antarctic sea, Skottsberg on 223; assimilation of organic acids by, Tréboux on 147; reed vegetation, Svedelius on 223
Alisma arcuatum **angustissimum** 211; in North Dakota 209; **lanceolatum** 211
Allen, C. E., personal 296
Allium, Bush on 146
Alsinoideae, Gibbs on 349
Alternaria Solani, Jones and Morse on 70
Aluminum, Rothert on relation of plants to 78
American Association for the Advancement of Science, Chicago meeting 152
American Society of Naturalists 232
Amorpha, angustifolia 299, 301, 302, 303, 304; californica 299, 301, 303; *californica* 301, 304, 306; canescens 297, 300; caroliniana 298, 302, 303; *caroliniana* 304; crocealanata 305; *cyanostachya* 302; fruticosa 299, 302, 304, var. **crocealanata** 305, var. **humilis** 305; *fruticosa* 305, var. *subglabra* 303, 307; *georgiana* 305, 306; glabra 298, 302; *glabra* 302; herbacea 297, 299, var. **Boyntoni** 300; hispidula 298, 301; *humilis* 303, 305; laevigata 299, 306, var. pubescens 307, f. **mollis** 307; *laevigata* 302; microphylla 298, 301; *montana* 302; *nana* 301, 305; *nonperforata* 305; nitens 299, 305, 306; paniculata 298, 306, 307; *pumila* 299, 305; *pubescens* 299; *Roemeriana* 307; **Schwerini** 298, 301; *subglabra* 307; Tennessensis 299, 303, 304; texana 299, 307, var. *mollis* 307; virgata 299, 305.
Amsinckia, Heller on 147
Anatomy and classification of ferns, Pelourde on 293
Anatomy, of cycads, Matte on 144; of roots, Holm on 79; of Rubiaceae 153; of Urticaceae, Renner on 295
Andean plants, Urban on 71
Aneura pinguis, Němec on 143
Angiosperms, Koernicke on centrosomes 290; and pteridosperms, Oliver on 228
Angora, Heller on 147
Antarctic sea, Skottsberg on algae of 223
Antennaria, Bush on 146
Anthemis Cotula, Fawcett on 348
Anthoceros, Peirce on 147
Anthracnoses, fungi producing 259
Anti-enzyme, Czapek on 142
Apogamy in Elatostema, Treub on 292
Apparatus, Habermann on filiform 289; use in plant physiology 274
Arabis, Nelson and Kennedy on 231
Arescboug, F. W. C., work of 148
Artari, A., work of 145
Arthur, J. C., personal 296, 359; work of 71, 146
Assimilation of organic acids by algae, Tréboux on 147
Aster adscendens, Fawcett on 348
Atkinson, G. F., personal 152, 359

B

Bacteria, and mineral salts, Benecke on 286; purple, Molisch on 151
Bacterium vascularium, Cobb on 70
Bag-worm, Von Schrenk on constriction of twigs by 226
Baker, C. F., 330
Ball, W. L., work of 227, 354
Balsamocitrus, Stapf on 146
Barnes, Charles Reid, 59, 68, 78, 141, 140, 142, 143, 144, 145, 147, 148, 150, 215, 216, 218, 226, 227, 285, 288, 295, 351, 355, 357, 420, 423

Bartram's oak 49
Baur, E., work of 287
Benecke, W., work of 286
Berberis, stamens, Juel on 353
Bergen and Davis' "Laboratory and field manual of botany" 423; "Principles of botany" 64
Berger, A., work of 146
Berlin, museum building 152
Bessey, C. E., personal 152; work of 150
Betula **Andrewsii** 281; papyrifera 279
Biological laboratory, Brooklyn Institute 359: Harpswell 424; Marine 359; Minnesota 358; Ohio Lake 358
Biometry, Fawcett on 348; Pearl on 348
Birch, new 279; rope, Penhallow on 291
Blackman, V. H., work of 289
Blakeslee, A. F., 415; personal 424
Blanchard, W. H., work of 71, 146, 230, 347
Blankinship, J. W., personal 232
Bleeding, Wiegand on 79
Blepharoplast, homology of, Ikeno on 291
Boraginaceae, Van Tieghem on 147
Borge, O., work of 223
Botanists of the Central States, third annual meeting 360
Brackett, M. M., personal 359
Brand, A., work of 348
Brassica oleracea, formation of mechanical tissue 372
Britten's "List of British seed-plants and ferns" 347
Britton, N. L., personal 152, 360; and Mrs. N. L., personal 424
Brown, A. J., work of 294
Brown and Duvel, work of 290
Browneopsis, Huber on 71, 146
Bryologist 232
Bryum, Cardot and Thériot on 348
Bücher, H., work of 227
Bulbils and proembryo of Lamprothamnus, McNicol on 294
Burbank's work, DeVries on 142
Burlingham, G. S., work of 348
Burnham, S. H., work of 146
Bush, B. F., work of 146

C

Cakile, Heller on 231
Calceolaria, Dowell on 147
Caldwell, Otis W., 64, 330; personal 359
California, lichen distribution in the Santa Cruz peninsula 267
Calonyction, *campanulatum* 412; dubium 411
Calypogeia, Evans on 348
Campbell, D. H., work of 354
Campbell's "University textbook of botany" 422
Camptotrophism, Bücher on 227
Cannon, W. A., personal 360
Cantua, Brand on 348
Capsella, Schaffner on embryology of 149
Carano, E., work of 229
Cardot and Thériot, work of 348
Carex, Fernald on 71
Carothers, Ida Eleanor, 116
Castilleia, Nelson and Kennedy on 231; Rydberg on 348
Cathcartia, Prain on 71
Caulerpa, ecology and taxonomy of, Svedelius on 231
Cavara, F., personal 152
Cell, Němec on formation 231; wall, Palla on formation 292
Centrosomes, in angiosperms, Koernicke on 290; and blepharoplasts, Ikeno on 291
Cephalanthus occidentalis, anatomy of 155
Cephalotaxus, drupacea Lawson on 224; Fortunei, fertilization and embryogeny in 1
Ceratophyllum, Pearl on morphogenesis in 352
Ceratozamia 137; Matte on 145; *mexicana* 187; *robusta* 187
Chamberlain, Charles J., 76, 137, 145, 149, 151, 289, 290, 291, 292, 294, 295; personal 359
Chantransia, Collins on 71; Kylin on 223
Characeae, McNicol on 294
Chemotaxis, Kniep on 226
Chestnut disease, Murrill on 293
China, Masters on conifers in 78
Chlorophyceae, fresh-water, Borge on 223
Chlorosis, Baur on infectious 287
Chnoopsora, Dietel on 71
Chodat's "Principes de botanique" 420
Christ, H., work of 348
Christman, A. H., personal 296
Chromosomes and mutation 105
Chrysler, M. A., 229, 292, 294
Chrysothamnus, Nelson and Kennedy on 231
Chylisma, Heller on 147
Cladophora crispata, Möbius on 295
Clements, F. E., personal 424
Cobb, work of 70
Cockerell, T. D. A., 283; work of 71, 231
Coker, W. C., 1
Coleus tricolor, formation of mechanical tissue 376
Colletotrichum, ascogenous 259
Collins, F. S., work of 71
Collybia platyphylla, Magnus on 148
Conanthus, Heller on 147

Cone, lateral, of Pinus 205
Conifers of China, Masters on 78
Coniferales, seedlings of, Hill and Fraine on 77
Conspectus generis Amorphae 297
Contributors: Baker, C. F., 330; Barnes C. R., 59, 68, 78, 140, 141, 142, 143, 144, 145, 147, 148, 150, 215, 216, 226, 227, 285, 288, 295, 351, 355, 357, 420, 423; Blakeslee, A. F., 415; Caldwell, O. W., 64, 330; Carothers, I. E., 116; Chamberlain, C. J., 76, 137, 145, 149, 151, 218, 289, 290, 291, 292, 294, 295; Chrysler, M. A., 229, 292, 294; Cockerell, T. D. A., 283; Coker, W. C., 1; Coulter, J. M., 69, 71, 72, 74, 75, 78, 79, 138, 146, 148, 149, 150, 217, 224, 227, 230, 231, 285, 291, 292, 293, 294, 295, 347, 350, 353, 354, 356, 422; Cowles, H. C., 139, 140, 149, 150; Crocker, W., 229, 290; Douglas, G. E., 233; Ferguson, M. C., 419; Ganong, W. F., 274, 340; Gates, R. R., 81, 146; Gow, J. E., 131; Hasselbring, H., 77, 147, 148, 251, 285, 287, 289, 293, 352, 354; Hefferan, M., 151, 286; Herre, A. W. C. T., 267; Hibbard, R. P., 361; Holm, T., 153, 308, 336; House, H. D., 408; Hoyt, W. D., 383; Jeffrey, E. C., 220, 228, 230; Jensen, G. H., 11; Johnson, D. S., 349; Land, W. J. G., 231; Lunell, J., 209; MacDougal, D. T., 45; Nelson, A., 279; Olive, E. W., 221; Pond, R. H., 73, 74, 78, 79, 142, 352, 353, 356; Rehder, A., 214, 281; Schneider, C. K., 297; Shaw, G. R., 205; Shear, C. L., 259; Shull, G. H., 75, 348, 356; Smith, F. G., 187; Thiessen, R., 144; Tilden, J. E., 223; Transeau E. N., 225; Vinson, A. E., 393; Wilcox, E. M., 70; Wood, A. K., 259; Wylie, R. B., 67
Convolvulaceae, new or noteworthy North American 408
Convolvulus, *roccineus* etc., 413; *macrorhizos* 413
Cook, Mel. T., personal 80, 358
Cooper, W. S., personal 359
Copeland, E. B., personal 296
Copper sulfate, effects on wheat 19
Coprinus, influence of gravity 254
Cordiaceae, Van Tieghem on 147
Correlation and leaf size, Ewart on 149
Correns, C., work of 356
Cotton, life-history of, Balls on 227
Cotyledons of Trollius, Ramaley on 79
Coulter, J. M., 69, 71, 72, 74, 75, 78, 79, 138, 146, 148, 149, 150, 217, 224, 227, 230, 231, 285, 291, 292, 293, 294, 295, 347, 350, 353, 354, 356, 422
Coulter's "Text book of botany" 66
Cowles, H. C., 139, 140, 149, 150; personal 359
Crataegus, Eggleston on 348
Crocker, Wm., 229, 290
Cryptanthe, Heller on 147; Nelson and Kennedy on 231
Cummings, Clara E., death of 152
Cyanophyceae, Gardner on cytology of 221
Cycadophyta, Oliver on 228
Cycads, and Ginkgo, Wettstein on origin of pollen tube 151; morphology of trunk and development of microsporangium 187; south African, Pearson on 292; vascular anatomy of, Matte on 144
Cycas circinalis 193
Cytology, of Cyanophyceae, Gardner on 221; of the Entomophthoraceae, Riddle on 76
Czapek, F., work of 142

D

Dalla Torre and Harms's "Genera Siphonogamarum" 218
Daniels' "Flora of Columbia, Missouri" 345
Darbishire, A. D., work of 75
Darkness, Němec on behavior of liverworts in 143
Darwin, F., work of 357
Dates, function of invertase in 393
Davis, B. M., personal 359
Dermocarpella, Lemmermann on 348
Degeneration, phenomena of pollen 100
Desmids, Nordstedt on nomenclature of 293
Deutsche Südpolar-Expedition 346
DeVries, Hugo; see Vries
Dianthera, an anatomical study 308
Dictyota dichotoma, periodicity in sexual cells of 383
Diels, L., personal 152; work of 348
Dietel, P., work of 71, 285
Diodia teres, anatomy of 171
Dioon edule 193
Dirina **franciscana** 270
Discomycetes, Duysen on wood-inhabiting 353
Disease, chestnut, Murrill on 293; cotton, Balls on 354; potato, Jones and Morse on 70; potato, Stewart, Eustace and Sirrine on 70; sugar cane, Cobb on 70; vine, Magnus on 148
Dorsiventrality in mosses, Němec on 351
Douglas, Gertrude E., 233
Dowell, P., work of 147
Drosera hybrid, Rosenberg on 146
Dunaliella, Teodoresco on biology of 150
Duysen, F., work of 353

E

Ecology 340; algae of antarctic 223; of Caulerpa, Svedelius on 231; of Georgia, Harper on 225; Gibbs on 78; of woodland plants, Woodhead on 74
Eggleston, W. W., work of 348
Ehretiaceae, Van Tieghem on 147
Elaeophorbia, Stapf on 230
Elatostema, Treub on apogamy in 292
Electroculture, Gassner on 355
Electrotropism of roots, Gassner on 219; Plowman on 351; Schellenberg on 218
Embryo of Spathyema foetida 136
Embryogeny, of Capsella, Schaffner on 149; of Cephalotaxus Fortunei 1
Embryo-sac mother cells in Lilium longiflorum 418
Encephalartos, Altensteinii 192; Caffer 192; Pearson on 292; *villosus* 187
Endemism, Willis on 353
Engler, A., work of 348; "Das Pflanzenreich" 285
Entomophthoraceae, Riddle on cytology of 76
Enzymes, Pantanelli on secretion of 357
Erigeron salsuginosus, Fawcett on 348
Errera, L., work of 79; "Recueil de l'institut botanique" 215, 347
Eriogonum, Heller on 147; Nelson and Kennedy on 231
Ernst, A., work of 229
Erythronium, Robertson on droppers of 75
Euphorbia, marginata, mutation of 283; Němec on cell-formation 231
Euterpe oleracea, Kränzlin on 229
Evans, A. E., personal 80; work of 347
Ewart, A. J., work of 149

F

Fairy rings, Thomas on rate of growth 77
Farmer, J. B., personal 152
Fawcett, H. S., work of 348
Ferguson, Margaret C., 419
Fernald, M. L., work of 71, 348
Fernow, B. E., personal 232, 359
Ferns of Costa Rica, Christ on 348; Pelourde on anatomy and classification of 293
Fertilization, and embryogeny in Cephalotaxus Fortunei 1; of Spathyema foetida 136
Festuca, Piper on 147
Field Museum of Natural History, herbarium of 424
Fimbriaria californica, Peirce on 147
Fitting's "Reizleitungsvorgänge" 346
Forestry, Bessey on 150
Formations, plant, at Victoria Falls, Gibbs on 78
Form-stimulus in fungi 251
Foxworthy, see Wiegand
Fraser, H. C. I., work of 289
Freeman, G. F., work of 356
Freezing, Gorke on 78
Fruits of Synedrella nodiflora, Ernst on 229
Fuchsia speciosa, formation of mechanical tissue in 375
Fungi, gravity as a form-stimulus in 251; Peck on 348; producing anthracnoses 259

G

Galium, circaezans, anatomy of 180; latifolium, anatomy of 182; pilosum, anatomy of 175; triflorum, anatomy of 179
Galtonia candicans, Němec on 231
Galvanotropism of roots, Gassner on 219; Plowman on 351; Schellenberg on 218
Gametophyte, development of, in Ginkgo biloba 116; male, of Zamia 198
Ganong, W. F., 274, 340; personal 359, 360
Garden, Missouri Botanical 232
Gardner, N. L., work of 221
Gassner, G., work of 219, 355
Gates, R. R., 81, 146
Geopanax, Hemsley on 230
Georgia, Harper on coastal plain of 225
Geotrophism, Bücher on 227
German south-polar expedition 346
Germination of dimorphic fruits, Ernst on 229
Gibbs, Miss L. S., work of 78, 349
Gilg, E., personal 80
Gilia, Brand on 348; Nelson and Kennedy on 231
Ginkgo, biloba, development of ovule and female gametophyte in 116; and cycads, Wettstein on origin of pollen tube 151
Gloeosporium, ascogenous 259
Glomerella, ascogenous 260
Glück's "Wasser- und Sumpfgewächse" 67
Glyceria, Hitchcock on 146
Glycogen and paraglycogen, Errera on 79
Gnomoniopsis 261
Godetia, Nelson and Kennedy on 231
Gongylanthus, Evans on 348
Gorke, H., work of 78
Gossypium, life-history of, Balls on 227
Gow, James Ellis, 131
Grass seed, Roberts and Freeman on Kansas 356; Brown on semipermeable membrane of 294
Gravity as a form-stimulus in fungi 251

Greene, E. L., work of 148
Growth, of fairy rings, Thomas on 77; Hedlund on 356; of lignified cell walls, Ursprung on 294; and respiration during winter, Simon on 73; of tree-trunks, Lignier on 75
Guignard, L., work of 288
Gymnogramme triangularis, Peirce on 147
Gymnosperms, Hill and Fraine on seedlings of 77
Gynodioecism and inheritance, Correns on 356
Györffy, I., work of 295

H

Habermann, A., work of 289
Haines, H. H., work of 146
Hamosa, Rydberg on 348
Hanbury, T., death 358
Harper, R. A., personal 296
Harper, R. M., work of 225
Harpswell biological laboratory 424
Harshberger, J. W., personal 296
Hasse, H. E., lichen collection of 232
Hasselbring, H., 77, 147 148, 251, 285, 287, 289, 293, 352, 354
Hassler, E., work of 230
Hedlund, T., work of 356
Hefferan, Mary, 151, 286
Helianthus annuus, formation of mechanical tissue 368, 375, 377, 380, 381
Heliotropiaceae, Van Tieghem on 147
Heller, A. A., personal 232; work of 147, 231
Hemsley, W. B., work of 230, 348
Hennings, P., on fungi of the German south-polar expedition 346
Herbarium, of Field Museum of Natural History 424; of H. E. Hasse 232; of Wm. Mitten 152; of J. Reverchon 232
Heredity, Darbishire on laws of 75
Herre, A. W. C. T., 267
Herriott, E. M., work of 150
Hesperastragalus, Heller on 147
Heterothallism in bread mold 415
Hibbard, R. P., 361
Hill, A. W., work of 72
Hill, T. G., work of 292; and Fraine, work of 77
Hitchcock, A. S., work of 146
Hollick A., personal 152
Holm, Theo., 153, 308, 336
Homalobus, Rydberg on 348
House, H. D., 408
Houstonia, anatomy of 161, 165
Hoyt, W. D., 383
Huber, J., work of 71, 146
Hulsea, Nelson and Kennedy on 231
Hyacinthus, Němec on 231
Hybrid, Drosera, Rosenberg on 146; list of natural 57; pollen development in 81
Hybridization of wild plants 45
Hydnum suaveolens, Thomas on 77
Hydrocyanic acid in plants, Guignard on 288
Hygroscopic mechanisms, Steinbrinck on 150
Hypnum, Cardot and Thériot on 348

I

Ikeno, S., work of 291
Illustrating botanical papers 59
Indokingia, Hemsley on 230
Inheritance and gynodioecism, Correns on 356
Integument of Ginkgo biloba 125
Intumescences on potato 233
Invertase in dates, function of 393
Ipomoea arborescens 410; **calva** 410; **ciervensis** 408; **collina** 412; **cuernavacensis** 410; dubia 411; *dubia* 411; *fistulosa* 409; **glabriuscula** 409; Grisebachiana 414; *Grisebachii* 414; heptaphylla 413; *heptaphylla* 413; **Lozani** 411; *macrantha* 411; *macrorhiza* 414; macrorhizos 414; marcorhiza 413; *marcorhizos* 413; **mestecensis** 411; **nicaraguensis** 409; *ornithopoda* 414; **petrophila** 408; **Plumieriana** 413; pulchella 414; *pulchella* 414; **rubella** 414; **silvicola** 411; tentaculifera 411; Wolcottiana 411
Iron, chlorid, and nitrate effects on wheat 33, 36

J

Janssonius' "Mikrographie des Holzes" 345
Jeffrey, E. C., 220, 228, 230; personal 358
Jensen, G. H., 11
Johnson, D. S., 349; personal 152, 359, 360
Jones and Morse, work of 70
Juel, H. O., work of 353

K

Kellerman, W. A., personal 80, 358; and Robinson, work of 77
Kennedy, P. B., work of 231
Kew, nomenclature at 296
Kjellman, F. R., death 424
Klebs, Georg, personal 232
Kniep, H., work of 226, 423
Koernicke, M., work of 290
Kostytschew, S., work of 295
Kraemer's "Textbook of botany and pharmacology" 422
Kränzlin, H., work of 229
Kratz, C., work of 352

Kuntze, O., death of 296
Kylin, H., work of 223

L

Laboratory, Brooklyn Institute 359; Harpswell 424; Woods Hole 359; Ohio Lake 358; Minnesota seaside 358
Laburnum vulgare, Baur on infectious chlorosis in 288
Lactarius, Burlingham on 348
Lagerberg, T., work of 149
Lamprothamnus, bulbils and proembryo of 294
Lamson-Scribner, F., work of 348
Land, W. J. G., 231
Langloisia, Brand on 348
Larix decidua, Němec on 231
Lathyropteris, Christ on 348
Lauraceae, Robinson on 71
Lavatera arborea, Baur on infectious chlorosis in 287
Lawson, A. A., work of 224
Lead nitrate, effects on wheat 22
Leaf, anatomy of rubiaceous 153; of Dianthera 325; of Ruellia 316; size and correlation, Ewart on 149; structure, Herriott on 150
Lecanactis Zahlbruckneri 270
Legume inoculation, Kellerman and Robinson on 77
Lejeunea, Němec on perception 143
Lemmermann, E., work of 348
Lewis, F. J., work of 71
Lewis, I. F., personal 359
Lichen, collection of H. E. Hasse 232; distribution in the Santa Cruz peninsula 267
Light, Peirce on formative influence of 147; screens 277
Lignier, O., work of 75
Ligustrum vulgare, Baur on infectious chlorosis in 288
Lilium longiflorum, two embryo-sac mother cells in 418
Linnaeus, 200th anniversary of birth 336, 424
Liverworts, Němec on behavior of in darkness 143
Livingston, B. E., personal 360; "Relation of desert plants to soil moisture and to evaporation" 216
Lloyd, C. G., "The Tylostomeae" 285
Lloyd, F. E., personal 358, 359, 360
Longo, B., work of 152
Lorch, Wm., work of 357
Lotsy, J. P., "Botanische Stammesgeschichte" 421; "Progressus rei botanicae" 138
Lunell, J., 209
Lupinus, Heller on 147; Rydberg on 348
Lutman, B. F., personal 296
Lyman, G., personal 359

M

Macbride, T. H., personal 360
MacCallum, W. B., personal 80, 360
MacDougal, D. T., 45; personal 360; and Earle and Richards, work of 358
McMurrich, J. P., personal 232
McNicol, Mary, work of 294
Macrozamia Miquelii 193
Magnus, P., work of 148
Marquette, W. G., personal 296
Massart, J., "Recueil de l'institut botanique" 215
Masters, M. T., work of 78
Matte, H., work of 144, 145
Mechanical tissue, influence of tension on formation of 361
Mechanics of plants, Lorch on 357
Meconopsis, Prain on 71
Medulloseae, a new type of, Scott on 230
Megasporangia, of Ginkgo 116; of Spathyema foetida 133
Melothria, Puccinia upon 282.
Membrane, semipermeable of grass seeds, Brown on 294
Microbahia, Cockerell on 231
Microcycas calocoma, identity of 330
Microsporangium, of cycads, development of 187; of Spathyema 131
Miehe, H., "Selbsterhitzung des Heus" 140
Millspaugh, C. F., personal 424
Minnesota, seaside station 358; greenhouses of University of 296
Mirabilis, Heller on 147
Missouri Botanical Garden 232
Mitchella repens, anatomy of 167
Mitosis, heterotypic, in Oenothera 94
Mitten, William, herbarium of 152
Miyake, K., personal 358
Möbius, M., work of 295
Möller, A., work of 79
Moisture in seeds, Brown and Duvel on 290
Mold, heterothallism in bread 415
Molisch, H., work of 151
Moll and Janssonius' "Mikrographie des Holzes" 345
Monocotyledons, Strasburger on stem-thickening in 229
Monotropis, Burnham on 146
Moore, G. T., personal 359
Morphogenesis in Ceratophyllum, Pearl on 352
Mosses, abnormal, Györffy on 295; dorsiventrality of, Němec on 351; Scottish peat, Lewis on 71

Motor mechanism of Berberis stamens, Juel on 353
Movement, Darwin on physiology of 357
Muhlenbergia 232; Lamson-Scribner on 348
Murrill, W. A., work of 293
Mutation, instance of 283; origin of species and varieties by 140; relation of pollen development to 81
Mycorhiza and nitrogen fixation, Möller on 79
Myers, W. S., "Food for plants" 217

N

Navarretia, Brand on 348
Neal, H. V., personal 424
Nelson, Aven, 279; and Kennedy, work of 231
Nelumbium luteum, Pearl on 349
Němec, B., work of 143, 351
Neoschimpera, Hemsley on 230
Nephlyctis, Arthur on 146
Newcombe, F. C., personal 360
New Uredinales, Arthur on 146
Nickel nitrate, effects on wheat 36
Nitrogen, fixation of atmospheric, Warmbold on 141; Möller on 79
Nomenclature 424; of desmids, Nordstedt on 293; at Kew 296
Nordstedt, C. F. O., work of 293
Nuclei, extra, in pollen tetrads 98
Nutrition, Artari on 145

O

Oak, Bartram's 49
Oedogoniaceae, Pascher on dwarf males of 291
Oenothera, hybrids 46; pollen development in 81
Ohio State University Lake laboratory 358
Oldenlandia glomerata, anatomy of 159
Olive E. W., 221; personal 296
Oliver, F. W., work of 228
Oospora scabies, Jones and Morse on 70
Ophioglossaceae, fertile spike of, Campbell on 354
Operculina angustiloba 414; *angustiloba* 414; **ornithopoda** 414; Roseana 414
Orcutt's "California Plants" 80
Oreocarya, Nelson and Kennedy on 231
Orthocarpus, Heller on 147
Orthotrichum, Cardot and Thériot on 348
Overton, J. B., personal 296
Ovule, of Cephalotaxus 2; development of, in Ginkgo biloba 116

P

Paleozoic botany, Scott on 220
Palisade cells, Raunkiaer on origin of 355
Palla, E., work of 292
Pandanaceae, Carano on 229
Pandanus utilis, Strasburger on 229
Panicum, Hitchcock on 146
Pantanelli, E., work of 357
Paraglycogen and glycogen, Errera on 79
Parthenogenesis in Wikstroemia, Winkler on 76
Pascher, A., work of 291
Pearl, R., work of 349
Pearson, H. H. W., work of 292
Peat mosses, Scottish, Lewis on 71
Peck, C. H., work of 348
Pedicularis, Rydberg on 348
Peirce, G. J., work of 147
Pellia, Němec on perception 143
Pelourde, F., work of 293
Penhallow, D. P., personal 232; work of 291
Pentacyphus, Ulrich on 71
Pentstemon, Heller on 147
Peperomia, Hill on geophilous species of 72
Periodicity in sexual cells of Dictyota 383
Personal: Allen, C. E., 296; Arthur, J. C., 296, 359; Atkinson, G. F., 152, 359; Bessey, C. E., 152; Blankinship, J. W., 232; Blakeslee, A. F., 424; Brackett, M. M., 359; Britton, N. L., 152, 360, and Mrs. 424; Caldwell, O. W. 359; Cannon, W. A., 360; Cavara, F., 152; Chamberlain C. J., 359; Christman, A. H., 296; Clements, F. E., 424; Cook, M. T., 80, 358; Cooper, W. S., 359; Copeland, E. B., 296; Cowles, H. C., 359; Cummings, C. E., 152; Davis, B. M., 359; Diels, L., 152; Evans, A. W., 80; Farmer, J. B., 152; Fernow, B. E., 232, 359; Ganong, W. F., 359, 360; Gilg, E., 80; Hanbury, T., 358; Harper, R. A., 296; Harshberger, J. W., 296; Heller, A. A., 232; Hollick, A., 152; Jeffrey, E. C., 358; Johnson, D. S., 152, 359, 360; Kellerman, W. A., 80, 358; Kjellman, F. R., 424; Klebs, Georg, 232; Kuntz, O., 296; Lewis, I. F., 395; Livingston, B. E., 360; Lloyd, F. E., 358, 359, 360; Longo, B., 152; Lutman, B. F., 296; Lyman, G., 359; Macbride, T. H., 360; MacCallum, W. B., 80, 360; MacDougal, D. T., 360; McMurrich, J. P., 232; Marquette, W. G., 296; Miyake, K., 358; Millspaugh, C. F., 424; Moore, G. T., 359; Neal, H. V., 424; Newcombe, F. C., 360; Olive, E. W., 296; Overton, J. B., 296; Penhallow, D. P., 232; Pfitzer, E., 80; Schneck, J., 358; Schrenk, H. von, 232; Scott, D. H., 152; Smith, A. M., 232; Spalding,

V. M., 360; Stickney, M. E., 358; Tansley, A. G., 152; Thaxter, R., 232; Thornber, J. J., 360; Thorndike, E. L. 232; Transeau, E. N., 359; Trelease, W., 232; Wiegand, K. M., 358; Wilcockson, L. M., 152; York, H. H., 359
Petiole, of Dianthera 327; of Ruellia 318
Pfitzer, Ernst, personal 80
Phacelia, Heller on 147
Phaseolus multiflorus, formation of mechanical tissue 373
Phenol, effects on wheat 38
Philippine Journal of Science 80
Phlox, Brand on 348; Heller on 147; Nelson and Kennedy on 231
Phoenix dactylifera, function of invertase in 393
Photosynthesis, Usher and Priestly on 144
Phototropism, Kniep on 423
Phycophaein, Tswett on 74
Physiology, appliances for use in plant 274; of movement, Darwin on 357; investigation of life-histories 340
Phytophthora infestans, Jones and Morse on 70
Pierreodendron, Engler on 348
Pinus, characters of 205
Piper, C. V., work of 147
Plant World, 359
Plowman, A. M., work of 351
Poisons, effect of wheat, 11
Polemoniaceae, Brand on 348
Polioma, Arthur on 146
Pollen, development in hybrids 80; grain of Cephalotaxus 2; tube of cycads and Ginkgo, Wettstein on 151
Polystictus, gravity as a form-stimulus in 252
Pond, R. H., 73, 74, 78, 79, 142, 352, 353, 356
Populus, Haines on 146
Potato, diseases, Jones and Morse on 70, Stewart, Eustace, and Sirrine on 70; formation of intumescences on 233
Prain, D., work of 71
Presynapsis and synapsis, Lagerberg on 149
Proembryo of Lamprothamnus, McNicol on 294
Prospodium, Arthur on 146
Prothallium of Ginkgo biloba 116
Pseudomachaerium, Hassler on 231
Psoralea, Bush on 146
Pteridophytes, Hill on secondary thickening in 292
Pteridosperms and angiosperms, Oliver on 228
Puccinia **melothriae** 283
Pyrenomycetes, Kratz on relation to substratum 352

Q

Quercus, heterophylla 49; marylandica 53; Phellos 53; rubra 53; Rudkinii 53

R

Raillardella, Nelson and Kennedy on 231
Ramaley, F., work of 79
Raunkiaer, C., work of 355
Ravenelia, monograph of, Dietel on 285
Rehder, A., 214, 281
Rendle, A. B., "List of British seed-plants and ferns" 347
Renner, O., work of 295
Respiration, aerobic, Kostytschew on 295; during winter, Simon on 73; Stoklasa on 357
Respirometer 274
Reverchon, J., herbarium of 232
Reviews: Bergen and Davis' "Laboratory and field manual of botany" 423, "Principles of botany" 64; Britten's "List of British seed-pla. .s and ferns" 347; Campbell's "University text book of botany" 422; Chodat's "Principes de botanique" 420; Coulter's "Textbook of botany" 66; Dalla Torre and Harms's "Genera Siphonogamarum" 218; Daniels' "Flora of Columbia, Missouri" 345; "Deutsche Südpolar-Expedition" 346; Engler's "Das Pflanzenreich" 285; Errera's "Recueil de l'institut botanique" 215, Tome II, 347; Fitting's "Reizleitungsvorgänge" 346; Glück's "Wasser- und Sumpfgewächse" 67; Janssonius' "Mikrographie des Holzes" 345; Kraemer's "Textbook of botany and pharmacology" 422; Livingston's "Relation of desert plants to soil moisture and to evaporation" 216; Lloyd's "Tylostomeae" 285; Lotsy's "Botanische Stammesgeschichte" 421, "Progressus rei botanicae" 138; Massart's "Recueil de l'institut botanique" 215; Miehe's "Selbsterhitzung des Heus" 140; Moll and Janssonius' "Mikrographie des Holzes" 345; Myers's "Food for plants" 217; Royal Society's "International catalogue of scientific literature" 218; Rendle's "List of British seed-plants and ferns" 347; Rose's "Mexican and Central American plants" 69; Schimmel and Co.'s "Semi-annual report" 218; Schneider's "Handbuch des Laubholzkunde" 214; Stoneman's "Plants and their ways in south Africa" 139; DeVries's "Species and varieties" 140; Wiegand's and Foxworthy's "Key to the genera of woody plants" 217

Rhinanthus, Fernald on 348
Rhizome of Ruellia 314
Rhizopus nigricans, heterothallism in 415
Rhododendron albiflorum with double flowers 281
Rhus glabra, segregates of, Greene on 148
Ribes, Heller on 231; Nelson and Kennedy on 231
Ricinus communis, effect of tension on formation of mechanical tissue 370, 378, 381
Roberts, H. F., work of 356
Root, anatomy of, Holm on 79; anatomy of rubiaceous 153; of Dianthera 319; influence of tension on 377, 379; galvanotropism of 218, 219, 351; rot of vine, Magnus on, 148; of Ruellia 312
Rosenberg, O., work of 146
Riddle, L. W., work of 76
Robertson, Agnes, work of 75
Robinson, B. L., work of 71
Rose, J. N., "Mexican and Central American plants" 69
Rothert, W., work of 78
Royal Society, "International catalogue of scientific literature" 218
Rubiaceae, anatomical studies of North American 153
Rubus, Blanchard on 71, 146, 230, 347
Ruellia, an antomical study 308
Rydberg, A., work of 348

S

Salts, mineral, and bacteria, Benecke on 286; and poisons, effect on wheat 11
Sap, ascent of, Pringsheim on 73; Wiegand on 79
Schaffner, J. H., work of 294
Schaffner, Mabel, work of 149
Schenck, on vascular plants of the German south-polar expedition 346
Schellenberg, H. C., work of 218, 423
Schiffner, on liverworts of the German south-polar expedition 346
Schimmel and Co., "Semi-annual report" 218
Schistonema, Ulrich on 71
Schizophyllum, gravity as a form-stimulus 253
Schneck, J., death 358
Schneider, C. K., 297; "Handbuch der Laubholzkunde" 214
Schrenk, H. von, personal 232, 226
Scott, D. H., personal 152; work of 220, 230; and Maslen, work of 350
Scottish peat mosses, Lewis on 71
Screens, light 277
Secondary thickening, Schellenberg on 423
Secretion of enzymes, Pantanelli on 357
Seed, Alsinoideae, Gibbs on 349; grass, Brown on semipermeable membrane of 294, Brown and Duvel on moisture in 290; of Trigonocarpus, Scott and Maslen on 350
Seedlings of gymnosperms, Hill and Fraine on 77
Senecio triangularis, Fawcett on 348
Sexual cells of Dictyota dichotoma, periodicity in 383
Sexuality of the Uredineae, Blackman on 289; Fraser on 289
Seychellaria, Hemsley on 348
Shaw, G. R., 205
Shear, C. L., 259
Shull, G. H., 75, 348, 356
Silphium, Bush on 146
Silver nitrate, effects on wheat 25
Simon, S., work of 73
Skottsberg, C., work of 223
Sloetiopsis, Engler on 348
Smith, Annie M., personal 232
Smith, Frances Grace 187
Sophia, Nelson and Kennedy on 231
Spalding, V. M., personal 360
Spathyema foetida, morphology 131
Species and varieties, origin by mutation, 140
Sphaerostigma, Nelson and Kennedy on 231
Spiraea lobata, Robinson on 71
Spirechina, Arthur on 146
Sporangia of Zamia floridana 192
Sporophylls of Zamia, development of 191
Stamens, Juel on Berberis 353
Stangeria, paradoxa 194; Pearson on 292
Stapf, O., work of 146, 230
Steinbrinck, C., work of 150
Steleostemma, Ulrich on 71
Stelmatocodon, Ulrich on 71
Stem, anatomy of rubiaceous 153; of Dianthera 320; influence of compression on 374; influence of tension on 366; of Ruellia 315; thickening in monocotyledons, Strasburger on 229
Stenochlaena, Underwood on 347
Sterility, causes of in hybrids 103
Stewart, Eustace and Sirrine, work of 70
Stichococcus, Artari on 145
Stickney, M. E., personal 358
Stimulation effects of some salts and poisons on wheat 11
Stoklasa, J., work of 357
Stoneman, B., "Plants and their ways in South Africa" 139
Strasburger, E., work of 229
Synapsis, and presynapsis, Lagerberg on 149; and synizesis, Schaffner on 294
Synedrella nodiflora, Ernst on 229
Synizesis and synapsis, Schaffner on 274

Syntrichopappus Lemmoni, Cockerell on 231
Svedelius, N., work of 223, 231

T

Tansley, A. G., personal 152
Taxicoscordion, Heller on 147
Taxonomy, 71, 146, 230, 347; of Caulerpa, Svedelius on 231
Tension, influence on formation of mechanical tissue 361
Teodoresco, E. C., work of 150
Tetraphysa, Ulrich on 71
Tetrastemma, Diels on 348
Thaxter, R., personal 232
Thickening, secondary, Hill on 292; Schellenberg on 423; Ursprung on 294
Thiessen, R., 144
Thomas, Fr., work of 77
Thornber, J. J., personal 360
Thorndike, E. L., personal 232
Thyridopteryx, von Schrenk on deformation of twigs by 226
Tilden, Josephine E., 223
Tithymalus **marginatus** 284; **tetramerus** 284
Tium, Rydberg on 348
Tracyacanthus, Bush on 146
Tradescantia, Cockerell on 71
Tragia, Bush on 146
Transeau, E. N., 225; personal 359
Transpiration, Areschoug on 148
Tréboux, O., work of 147
Tree-trunks, Lignier on radial growth of 75
Trelease W., personal 232
Treub, M., work of 292
Trifolium, Kennedy on 231; Rydberg on 348
Trigonocarpus, Scott and Maslen on 350
Trollius, Ramaley on cotyledons of 79
Trunk of cycads, morphology of 187
Tswett, M., work of 74
Tulipa, Robertson on droppers of 75
Turgor in wilting plants, Pringsheim on 73
Twigs, von Schrenk on constriction by bag-worm 226

U

Ulrich, E., work of 71
Underwood, L. M., work of 347
Urban, I., work of 71
Uredineae, Arthur on 71; Dietel on 71; Blackman on sexuality of 289; Fraser on, 289
Ursprung, A., work of 294, 423
Urticaceae, anatomy of, Renner on 295
Usher and Priestly, work of 144

V

Van Tieghem work of 146
Vicia Faba, Němec on 231
Vinca major, formation of mechanical tissue in 371, 375
Vinson, A. E., 393
Von Schrenk, H., see Schrenk
Vries, Hugo de, work of 142; "Species and varieties" 140

W

Walls, growth of lignified cell, Ursprung on 294, 423
Warmbold, H., work of 141
Washingtonia filifera, Strasburger on 229
Waterbloom, Möbius on 295
Water movement and turgor in wilting plants, Pringsheim on 73
Weberbauerella, Ulrich on 71
Wettstein, R., 151
Wheat, toxic limits and stimulation effects of some salts and poisons on 11
Wiegand, K. M., personal 358; work of 79; and Foxworthy's "Key to the genera of woody plants" 217
Wikstroemia, parthenogenesis in, Winkler on 76
Wilcockson, Lilian M., personal 152
Wilcox, E. Mead, 70
Willis, J. C., work of 353
Wilson, G. W., work of 348
Winkler, H., work of 76
Wirth on ecology of the German south-polar expedition 346
Wisconsin Academy of Sciences 296
Wood, Anna K., 259
Woodhead, T. W., work of 74
Woodland plants, Woodhead on 74
Wylie, Robert B., 67

X

Xanthium, Bush on 146
Xylophacos, Rydberg on 348

Y

York, H. H., personal 359

Z

Zahlbruckner on lichens of the German south-polar expedition 346
Zamia, *calocoma* 330; floridana 187, development of sporophylls 191, sporangia 192; pumila 330
Zinc sulfate, effects on wheat 30